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Industrial Hygiene

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Journal

VOLUME 19, NUMBER 5

OCTOBER 1958

Pangborn Dust Control

gives you healthier, happier employees!

Pangborn Dust Collectors trap industrial dusts controlled at the source of origin. By doing so, they reduce the health-hazard of industrial dust. Employee health is safeguarded . . . morale is higher, efficiency is increased.

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4. Cutting heating costs. Many plants recirculate the already-heated cleaned air.

In addition, Pangborn Dust Control guards product quality and improves community relations outside.

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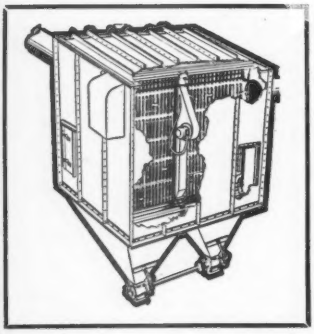
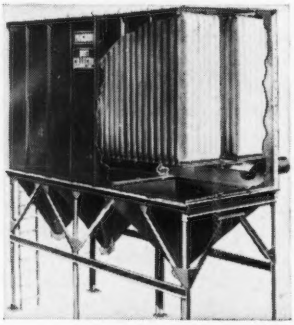
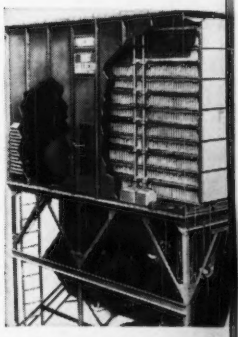


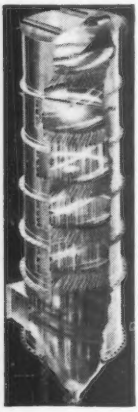
For automatic, *continuous* operation, the Pangborn Self-Cleaning Collector — combining the proved efficiency of the cloth screen collector with continuous operation, uniform air flow.



Also for dry dusts, the Pangborn Cloth Bag Collector—an efficient, economical method of dust control. Its simplified design and construction involves a minimum of parts. Easily inspected and maintained.



For fine, dry dusts, the Pangborn Screen Collector—accomplishes recovery at low cost; easily tained and gives maximum area for the space availabl



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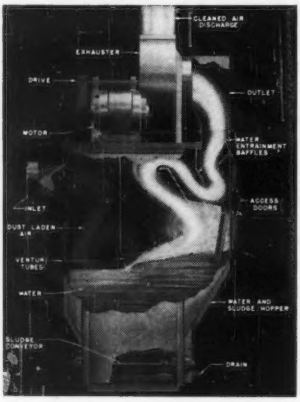
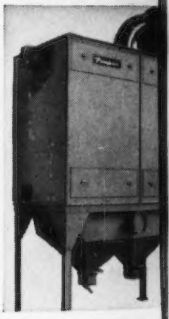


The Pangborn Ventrijet Wet Collector—also for dusts that a dry type collector cannot handle. A compact, self-contained unit with low headroom. Inexpensive to maintain and operate, its ease and economy of installation recommend its use in many cases.



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NOTE: Bulletins are available on all Pangborn Dust Collectors. For your copy or more details, write PANGBORN CORP., 4500 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Dust Control and Blast Cleaning Equipment.*

Pangborn CONTROLS DUS

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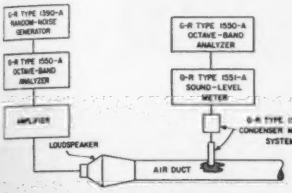
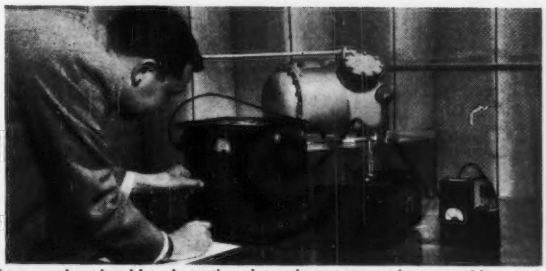


Noise can be effectively reduced by proper design of system fittings. The block diagram shows a setup which is used to generate and measure air-duct sound-pressure levels. In this way, the amount of attenuation provided by the duct is determined. The Random-Noise Generator simulates fan noise, and the Octave-Band Noise Analyzer used with it provides the necessary filtering to remove extraneous background noise.



Here, sound produced by a hermetic reciprocating compressor is measured in a semi-anechoic sound room. Compressor noise is picked up by the microphone, amplified by the Sound-Level Meter, and fed to the Octave-Band Analyzer for broad-band frequency analysis. Also shown is the G-R Type 1307-A Transistor Oscillator and Type 1552-B Sound-Level Calibrator for convenient calibration of the complete Sound-Level-Meter System from microphone to meter.

Engineer measures over-all sound level produced by a Carrier Automatic Absorption Refrigeration Machine in central-station installation. This installation has 500-ton capacity and uses low-pressure steam to provide chilled water for the entire system.

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President's Page

One year ago an ad hoc committee appointed to study the need for certification in the field of industrial hygiene recommended to AIHA's Board of Directors that a certification plan be developed. The Board accepted the committee's recommendation.

Early this year a Joint AIHA-ACGIH Committee on Certification Standards was formed under the chairmanship of Henry F. Smyth, Jr. With characteristic vigor Dr. Smyth has led his committee through the early stages of planning, and it is now possible to report some of the important features of the contemplated certification program.

There will be an independent, incorporated certifying body—the American Board of Industrial Hygiene—composed of six representatives of AIHA, six of ACGIH, and one from each of four societies concerned with disciplines that are a part of industrial hygiene.

For the first year following public announcement of the availability of certification, applicants may be certified without examination. Those so certified must have had 19 years of industrial hygiene practice, must have been in a responsible position in a full-time industrial hygiene program (or in a contributing specialty with a major part of the time applied to industrial hygiene) for at least five of the 19 years, and must be engaged in practice at the time of application. Formal academic training in a contributing specialty may be considered equivalent to as much as four years of practice.

For certification by written examination an applicant must have a bachelor's degree in a contributing specialty, must have had eight years of practice, and must be currently engaged in practice. The requirement of eight years of practice may be partially met by credit for advanced degrees. In exceptional cases the Board may recognize long and competent practice as equivalent to the bachelor's degree.

Written examinations will ordinarily be given annually during the two days immediately preceding or following the Industrial Health Conference and in the same city as the Conference. In addition however, the examinations may be given occasionally in areas distant from the conference city.

It is expected that the detailed certification plan will be presented to the memberships of AIHA and ACGIH before the 1959 Industrial Health Conference and that approval of the plan will be sought at the annual business meetings of the two societies.

Kenneth W. Nelson

AMERICAN

Industrial Hygiene

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YOU CAN DEPEND ON DOW

Toxicity of 1,1,1-Trichloroethane as Determined on Laboratory Animals and Human Subjects

T. R. TORKELSON, F. OYEN, D. D. McCOLLISTER, and V. K. ROWE

Biochemical Research Laboratory
The Dow Chemical Company, Midland, Michigan

Introduction

IN THE past few years, 1,1,1-trichloroethane (methyl chloroform) has become widely used as a solvent. It is particularly useful in cold degreasing applications and as a bucket solvent for cleaning metal parts, electric motors and other equipment. Literature references on the toxicity of this material are limited, undoubtedly because of the relatively short period of commercial utilization. Several references contain a serious error. Lehmann and Flury[1], Browning[2], Elkins[3], Fairhall[4], and Saks[5, 6] all consider the 1,1,1-isomer to be more toxic than 1,1,2-trichloroethane or make no distinction between the two isomers. Their conclusions are apparently all based on an error in summary by Lehmann and Flury of the original work published by Lazarew.[7] In this work Lazarew conducted single exposures of two hours with groups of mice in a ten liter container and noted the concentrations producing various stages of anesthesia. These data are summarized as follows:

	Minimale Konzentration der Dämpfe für		
Trichloroäthan	Seitenlage	Verlust Der Reflexe	Tod
1,1,2-	10 mg./l.	15 mg./l.	60 mg./l.
1,1,1-	40 mg./l.	45 mg./l.	65 mg./l.

While these data demonstrate that the 1,1,1-isomer has a lower toxicity, the converse was stated by Lehmann and Flury. A correct summary of Lazarew's data was published by Patty[8] and also by von Oettingen[9] who points out that the 1,1,1-isomer is considerably less toxic than the 1,1,2-trichloroethane.

Recently additional information has been published by Carpenter, Smyth and Pozzani.[10] These authors reported that a single four-hour exposure to a concentration of 2000 ppm of 1,1,2-trichloroethane resulted in the death of approximately 50% of the experimental rats exposed. Data published by Adams et al.[11] show that a single four-hour exposure of 16,000 ppm would be necessary to kill 50% of the rats exposed to 1,1,1-trichloroethane. By this measure the acute vapor toxicity of the 1,1,1-isomer is markedly less than that of the 1,1,2-isomer.

Adams et al.[11] also reported that acute deaths were due to depression of the central nervous system and that the 1,1,1-isomer had little capacity to cause organic injury from either single or repeated exposure to vapors.

The present experimental work was undertaken to supplement this previously published data and to provide a more adequate basis for evaluating the hazards involved in use. It was also desired to compare the toxicity of the inhibited material with that of the uninhibited.

This report includes the results of animal experiments designed to determine the effects of the liquid material upon the skin and eyes of rabbits, of intragastric administration of single doses to various species, and of repeated inhalation of the vapor by various species. In addition, laboratory and field experience with human subjects is described.

Materials Tested

Physical and chemical properties

1,1,1-Trichloroethane, CH_3CCl_3, is a colorless pleasant smelling liquid having a specific gravity of 1.336 at 25°C/25°C and a boiling point of 74.1°C. The vapor pressure of 1,1,1-trichloroethane has been determined[12] and is given together with that of several other commonly used chlorinated solvents in Figure 1. Like many chlorinated hydrocarbons, this material reacts readily with aluminum and aluminum alloys, therefore it must be inhibited if corrosion is to be prevented.

The inhibited product studied was Chlorothene[13], samples of which were shown by infrared analysis to contain 94% to 97% 1,1,1-

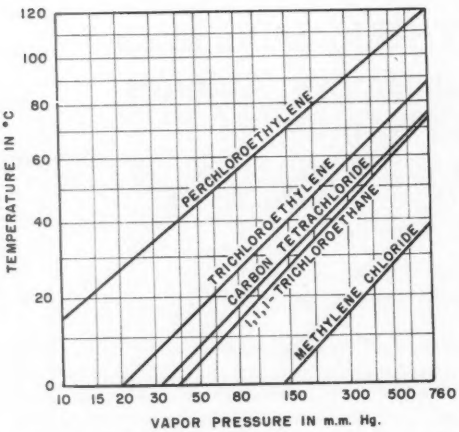

FIGURE 1. Vapor pressures of several commonly used chlorinated solvents.

trichloroethane, 2.4% to 3.0% dioxane, 0.12% to 0.3% butanol, and small amounts of ethylene dichloride, water and other materials. The vapor pressure of Chlorothene has been shown to be essentially the same as that of 1,1,1-trichloroethane.[12]

THERMAL STABILITY AND FLAMMABILITY

Crummett and Stenger[14] have studied the products resulting from thermal decomposition of uninhibited or inhibited 1,1,1-trichloroethane. Little decomposition of the vapor occurs until the temperature approaches 500°F. At this and higher temperatures large amounts of hydrogen chloride are formed but only small amounts of phosgene. The hydrogen chloride formed in all cases was adequate to provide warning properties if an individual should be exposed to the resulting vapors. Hence, harmful exposures are not likely to occur unless escape is barred.

The flammability of inhibited 1,1,1-trichloroethane has been shown to be similar to that of trichloroethylene[12] and therefore a fire hazard exists only at concentrations which would be rapidly anesthetic. According to our experiene, neither inhibited 1,1,1-trichloroethane nor trichloroethylene has a flash point or a fire point using the standard ASTM procedures for the Tag closed cup and Cleveland open cup tests. Both materials will decompose if a source of heat is supplied, but neither will support combustion and therefore do not materially add to a fire.

The limits of flammability of the vapors of inhibited 1,1,1-trichloroethane have been found to be 10% to 15.5% in air with hot wire ignition, if considerable energy is used for ignition. Using spark discharge under comparable conditions over 2.8 joules were required in a test for which only 0.001 joules were required for hexane.[15] The large amount of energy required indicates that sparks from most sources of static electricity, or from friction grinding or chipping probably will not ignite the vapors of 1,1,1-trichloroethane. However, if large amounts of heat, such as an open flame or a red hot wire are applied, the vapors in the above mentioned concentrations could burn.

If a single container of inhibited 1,1,1-trichloroethane is used or re-used over a long period of time without being totally emptied, the concentration of dioxane can increase due to its slightly lower vapor pressure. Considerable concentration is required, however, before flammability becomes a problem. Tests indicate that evaporation to 15 to 20% of the original volume does not result in the material developing a flash point. However, if the material is reduced to 10% of the original volume (concentration of dioxane approaches 13%) a flash point of 115°F becomes possible. Such concentration is likely to result only after long use or in reclammation by distillation. In such cases, the residue can become flammable.

Experimental Procedures

ORAL ADMINISTRATION, EYE CONTACT, SKIN CONTACT, AND SKIN ABSORPTION

The animals and methods used for determining the toxicity from single oral dose, eye contact, skin contact, and acute skin absorption have been previously described.[16] Both the inhibited and uninhibited materials were tested.

REPEATED SKIN APPLICATION, 90 DAYS

Work described under this heading was done for The Dow Chemical Company by The Industrial Biology Research and Testing Laboratories.[17]

Adult male albino rabbits which had been observed for two weeks to assure normalcy were divided into nine groups of four rabbits each for purposes of dosing. The skin of two of the four rabbits from each group was abraded; these abrasions were renewed weekly. The rabbits which were restrained in stocks during the application period were placed in a fume hood with only their heads protruding to prevent incidental inhalation of the vapors. The rabbits were weighed weekly and the dosages adjusted to the body weight. The total daily doses were divided into four equal parts

which were administered directly to the shaven skin of the rabbits without cover at 10:00 a.m., 12:00 noon, 2:00 p.m. and 4:00 p.m. respectively. The doses shown were administered on the basis of a five-day week:

Group	Treatment
Controls—Unexposed	Handled but without treatment.
Control—Isopropanol	15, 100 and 500 mg/kg/day.
Exposed—Inhibited 1,1,1-trichloroethane	15, 50, 100, 200 and 500 mg/kg/day.

Blood studies including hemoglobin, red blood cell count, white blood cell count, and differential count as well as icterus index, were made at the beginning of the study and at the end of 30 and 90 days. One rabbit from each group was sacrificed after 30 days and another after 90 days for gross and microscopic study of the brain, heart, lung, liver, kidney, spleen, stomach, testes, thyroid, intestine and skin from the area of contact. The organs were weighed with the exception of the intestine and skin. The remaining animals were maintained without further treatment for 30 days for the purpose of observing any latent effects which might occur. They were then autopsied as described.

Repeated vapor exposures

The material tested in the vapor experiments was the commerical inhibited 1,1,1-trichloroethane (Chlorothene). The source and feeding of animals used and the techniques and exposure chambers employed were essentially the same as those previously described.[18] The glass wall chamber (160-liter capacity) which was described for single exposures was used for the short term repeated exposures to 1000, 2000 and 10,000 ppm. The large metal chamber (1700-liter capacity) was used for the exposures to 500 ppm. All concentrations were checked repeatedly by combustion analysis and found to be within 10% of the stated values. All exposures were continuously monitored by a conductivity combustion analyzer.[19]

For the exposures to 500 ppm, two sets of controls were kept; unexposed controls which were simply maintained in the animal quarters and air-exposed controls which were subjected repeatedly to room air in a chamber similar to that used for the animals exposed to vapors of the test material. Only air-exposed controls were maintained for exposures to 1000, 2000 and 10,000 ppm. Each animal was weighed twice a week until it was established that growth was normal after which they were weighed once a week. They were observed frequently for general appearance and behavior. Growth and mortality records were kept for each group. Failing animals were killed for examination. All survivors were killed and examined for evidence of organic injury on the day following the last exposure. The t-test[20] was used in comparing mean values of body weights and of organ weights, probability values (P) of 0.05 or less representing a significant difference.

Exposure of humans

Limited experiments to determine the effects on humans of breathing uninhibited 1,1,1-trichloroethane were conducted in a small room by vaporizing the liquid in a warm petri dish placed in front of a circulating fan. Concentrations were analyzed by direct combustion and subsequent titration of chloride by a micro-Volhard method. Groups of two to four individuals were exposed to each concentration.

Additional experiments were conducted in a 3700-liter stainless steel chamber. Concentrations were controlled using the metering equipment previously described.[18] The concentrations were analyzed by direct combustion as well as monitored continuously by a conductivity combustion analyzer.

Electrocardiograms were made during the course of the exposure. Blood and urine samples were taken before and after exposure and several hours later.

Cephalin flocculation and thymol turbidity tests for liver function were given after exposure. The Flanagan Aptitude Classification Test (7A Coordination) was given before and several times during the exposure. The Rhomberg test for equilibrium was given before and after exposure. All individuals were asked to report any subjective symptoms.

Results of Experiments

Oral administration—single doses

The single dose oral toxicities of uninhibited and inhibited 1,1,1-trichloroethane were determined by administering intragastrically, undiluted materials in single doses to white rats, guinea pigs, rabbits, and mice. The acute oral LD_{50}'s with the 19/20 confidence limits were calculated, where possible, by the Thompson method of moving averages.[21] The results of the statistical treatment of the dosage response data are presented in Table I.

Eye contact—rabbit

One application of the uninhibited or the inhibited material to the eyes of rabbits resulted in slight to moderate pain, slight con-

TABLE I

Acute Oral Toxicity of Uninhibited and Inhibited 1,1,1-Trichloroethane
Single doses, administered undiluted by intubation

Species	Uninhibited			Inhibited		
	Sex	Total number of animals used	LD_{50} (19/20 confidence limits) gm/kg	Sex	Total number of animals used	LD_{50} (19/20 confidence limits) gm/kg
Rats	M	35	12.3 (11.0 to 13.7)	M	40	14.3 (12.1 to 17.0)
Rats	F	35	10.3 (8.27 to 12.8)	F	50	11.0 (9.5 to 13.0)
Mice	F	16	11.24	F	40	9.7
Rabbits	F	16	5.66 (3.50 to 9.14)	Mixed	40	10.5 (9.7 to 11.3)
Guinea pigs	M	16	9.47 (3.47 to 13.3)	Mixed	30	8.6 (6.1 to 12.2)

junctival irritation but essentially no corneal damage. Any irritation which occurred disappeared within a few days. The reaction was similar to that seen with other organic solvents such as toluene and carbon tetrachloride.

SKIN CONTACT—RABBIT

Irritation. When a pad of absorbent cotton which had been saturated with either inhibited or uninhibited 1,1,1-trichloroethane was bandaged on the shaven belly of a rabbit only a slight reddening and scaliness occurred. When this procedure was repeated ten times in twelve days the reaction was increased only slightly. Healing occurred promptly when application ceased. When applied to the wounded skin neither material significantly altered the healing process.

Acute absorption, 24-hour application under a cuff. Uninhibited and inhibited 1,1,1-trichloroethane were each applied to groups of eight rabbits per dosage level. Both materials were found to be low in toxicity by this route. Doses of 3.98 gm/kg were survived by all animals treated. Doses of 15.8 gm/kg failed to kill half of the animals treated.

Repeated skin application, five days per week for 90 days. Repeated application (five days per week for 90 days) in daily dosages of 500 mg or less/kg body weight caused no adverse affects when judged on the basis of general apperance, behavior, food intake, mortality, growth, hematological examination, and gross and microscopic examination of the internal organs. The skin at the site of the repeated applications of both inhibited 1,1,1-trichloroethane and isopropanol showed slight reversible irritation as would be expected from such exposure to a fat solvent.

REPEATED VAPOR EXPOSURES

Five hundred ppm seven hours per day, five days per week for six months. Groups of 20 male and 20 female rats, 8 male and 8 female guinea pigs, 2 male and 2 female rabbits, and 2 female monkeys were exposed 126–130 times in a period of 180 days. Growth, general apperance and mortality records showed no evidence of adverse effects when compared to the controls. Hematological values were within normal limits (Table II). Gross and microscopic pathological examination showed no significant differences between the exposed and control animals. A summary of the organ weights, growth and mortality is given in Table III. A statistical comparison of organ weights likewise showed no significant differences between the exposed and control animals.

Ten thousand ppm, five days per week for three months. Seperate groups of five male rats each were exposed a total of 70 times in 99 days for periods of 1.0, 0.5, 0.2, and 0.1 or 0.05 hour per day.

The results of these exposures are summarized in Table IV. When judged on the basis of appearance, growth, mortality, gross pathology, micropathology and a statistical comparison of body, liver and kidney weights, the only evidence of organic injury was a barely significant increase in the liver weights of rats exposed for one hour per day. This concentration caused various degrees of anesthesia ranging from ataxia to semi-consciousness. The animals may have become acclimated to this material as they were obviously more affected by the exposure at the beginning of each week than they were by the fifth exposure of each week. This apparent acclimation has also been noted on dogs exposed to inhibited 1,1,1-trichloroethane in another experiment.[12]

Two thousand ppm, five days per week for three months. Separate groups of five female guinea pigs each were exposed 69 times in 98 days for periods of 0.5, 0.2, 0.1 or 0.05 hour per day. The results of these exposures are summarized in Table IV. Guinea pigs exposed

TABLE II

Average Hematological Values for Animals Receiving Repeated 7-Hour Exposures to 500 PPM Inhibited 1,1,1-Trichloroethane 5 Days/Week for Six Months

Species	Treatment	Sex	No. of animals	RBC × 10^6	WBC × 10^3	Hb gm/100 ml	Differential Count (%)			
							Neutrophils	Lymphocytes	Monocytes	Eosinophils
Rat	Air-exposed control	M	5	9.72	12.72	14.2	25.8	71.8	0.6	1.8
Rat	Experimental	M	5	9.25	14.57	14.4	15.2	82.8	0.8	1.2
Rat	Air-exposed control	F	5	9.21	11.03	13.4	18.4	79.4	0.8	1.4
Rat	Experimental	F	5	8.70	11.33	13.4	23.0	74.6	0.8	1.6
Monkey	Air-exposed control	F	2	4.42	17.00	10.8	59.5	39.0	1	0.5
Monkey	Experimental	F	2	5.61	17.15	11.5	39.5	57.5	0.5	2.5
Rabbit	Air-exposed control	M	2	6.17	11.17	12.0	10.5	89.5	0	0
Rabbit	Experimental	M	1	5.93	12.1	10.8	25.0	75.0	0	0
Rabbit	Air-exposed control	F	1	5.85	10.90	7.9	23.0	77.0	0	0
Rabbit	Experimental	F	1	5.25	11.75	10.6	7.0	92.0	0	0

TABLE III

Summary of Average Body and Organ Weights of Animals Receiving Repeated 7-Hour Exposures to 500 PPM Inhibited 1,1,1-Trichloroethane 5 Days per Week for Six Months

Species	Sex	Group	No. of surviving animals	Final average body weight, gm.	Organ weights, gm/100 gm body weight					
					Lung	Heart	Liver	Kidney	Spleen	Testes
Rat	M	Unexposed control	18	383	0.54	0.30	2.33	0.63	0.26	0.68
		Air-exposed control	18	378	0.51	0.30	2.43	0.64	0.25	0.78
		128 Exposures, 182 days	18	386	0.49	0.30	2.38	0.62	0.25	0.82
Rat	F	Unexposed control	18	247	0.62	0.33	2.34	0.64	0.24	
		Air-exposed control	17	246	0.63	0.33	2.58	0.68	0.31	
		130 Exposures, 184 days	19	236	0.67	0.36	2.67	0.70	0.30	
Guinea Pig	M	Unexposed control	7	1005	0.66	0.28	3.27	0.62	0.11	0.45
		Air-exposed control	8	879	0.74	0.28	3.32	0.71	0.11	0.46
		132 Exposures, 188 days	8	834[a]	0.74	0.29	3.52	0.63	0.11	0.45
Guinea Pig	F	Unexposed control	8	822	0.72	0.26	3.75	0.61	0.15	
		Air-exposed control	8	836	0.72	0.25	3.79	0.56	0.13	
		133 Exposures, 189 days	8	782[b]	0.83[c]	0.25	3.77	0.56	0.13	
Rabbit	M	Unexposed control	2[d]	3510	0.40	0.20	2.19	0.46	0.04	0.16
		Air-exposed control	2	2800	0.45	0.18	2.30	0.50	0.04	0.16
		134 Exposures, 190 days	1	3040	0.40	0.19	2.35	0.44	0.03	0.10
Rabbit	F	Unexposed control	2[d]	3800	0.31	0.18	2.23	0.38	0.03	
		Air-exposed control	1	3470	0.30	0.17	2.11	0.46	0.04	
		134 Exposures, 190 days	1	3360	0.29	0.17	2.72	0.47	0.03	
Monkey	F	Air-exposed control	2[d]	4850	0.68	0.35	2.43	0.38	0.11	
		135 Exposures, 191 days	2	4270	0.88	0.33	2.55	0.40	0.07	

(a) P = 0.4 (b) P = 0.3 (c) P = 0.054.
(d) P values were not calculated for rabbits and monkeys because of the small sample. The data are within normal limits.

for 0.5 hour per day exhibited irritation of the lungs and fatty changes in the liver. Appearance, growth and organ weights were normal when compared to the controls. Guinea pigs exposed for 0.2 hour per day were normal except for evidence microscopically of interstitial inflammation in the lungs and a somewhat increased incidence in the kidney of interstitial nephritis. Since this nephritis was not seen at higher intensities of exposure it is probably not related to the exposure. The animals exposed for 0.1 and 0.05 hour per day showed no effects when compared to the controls when judged on the basis of appearance, growth, mortality, gross pathology, micropathology, and a statistical comparison of body, liver, and kidney weight.

TABLE IV

Final Average Body and Organ Weights of Animals Receiving Repeated Exposures to High Concentrations of Inhibited 1,1,1-Trichloroethane 5 Days per Week for 3 Months 69–70 Exposures in 98–99 Days

Species	Sex	No. of surviving animals	Conc. ppm	Duration of daily exposure in hours	Average body weight gm	Average organ weight gm/100 gm body weight	
						Liver	Kidney
Guinea pig	F	5	Air-exposed control	3.0	738	3.86	0.72
Guinea pig	F	5	1000	3.0	692	4.60[a]	0.69
		5	1000	1.2	716	4.15[b]	0.69
		4	1000	0.6	718	3.98	0.68
		5	1000	0.3	697	3.82	0.70
Guinea pig	F	5	2000	0.5	781	4.08[c]	0.66
		5	2000	0.2	716	3.80	0.73
		5	2000	0.1	721	3.88	0.74
		5	2000	0.05	691	4.30	0.69
Rat	M	4	Air-exposed control	1.0	361	2.53	0.68
Rat	M	4	10,000	1.0	339	2.76[d]	0.70
		4	10,000	0.5	337[e]	2.56	0.74
		4	10,000	0.2	355	2.61	0.71
		5	10,000	0.1	358	2.53	0.68
		5	10,000	0.05	361	2.44	0.68

(a) P = .001 (b) P = 0.19 (c) P = 0.39 (d) P = 0.03 (e) P = 0.3

One thousand ppm, five days per week for three months. Separate groups of five female guinea pigs each were exposed 69 times in 98 days for periods of 3.0, 1.2, 0.6, or 0.3 hours per day. The results of these exposures are summarized in Table IV. The animals exposed 3.0 hours per day were less active and felt soft when handled. Growth was slightly retarded although final body weights were not significantly different from the controls (P = 0.26). There was evidence of inflammation in the lungs, central lobular fatty changes in the liver and a significant increase in liver weight when compared with the controls. Guinea pigs exposed 1.2 hours per day grew normally and were normal in appearance. Microscopically, however, there was evidence of inflammation and pneumonia in the lungs. Organ weights were normal in comparison to the controls. Guinea pigs exposed 0.6 and 0.3 hour per day showed no evidence of ill effects either grossly or microscopically when compared with the controls.

Exposure of humans

The results of tests on humans are summarized in Table V. Under practical conditions of use where it has been possible to obtain reliable data as to the intensity of exposure, results have verified the data obtained in the experiments on human subjects.

Significance of Results

Ingestion

Studies on four species of laboratory animals show that both uninhibited and inhibited 1,1,1-trichloroethane are low in single dose oral toxicity and for practical purposes their toxicities are the same. There should be no problem from ingestion in industrial handling. However, the swallowing of substantial quantities such as might occur accidentally or willfully could result in serious injury.

Eye contact

If splashed directly into the eye uninhibited and inhibited 1,1,1-trichloroethane may cause pain and soreness for a few days but neither is likely to cause any serious injury.

Skin contact

Prolonged and repeated contact with the skin resulted only in slight irritation unless the material was confined under an impermeable barrier. The response when confined on the skin was similar to that seen on prolonged exposure to other common solvents (carbon tetrachloride, ethylene dichloride, benzene, and perchloroethylene). Hence a considerable exposure during solvent use can be tolerated without ir-

TABLE V

Results of Single Exposures of Humans to the Vapors of 1,1,1-Trichloroethane

Concentration in ppm	Duration of exposure in minutes	Symptoms and response
546 (450-710)	90	No effect other than the smell of the chemical.
506 (415-590)	450	Moderate smell which tended to disappear. Examination made before and after exposure found no significant changes in pulse, respiration, blood pressure, reflexes and equilibrium. Tests for urinary urobilinogen, thymol turbidity and excretion of bromosulphalein did not indicate any significant changes in liver function.
1000 (890-1190)	30	Unpleasant odor, equilibrium apparently not disturbed.
920 (900-1000)	70-75	Two of the four individuals exposed reported a strong odor and one reported a slight eye irritation. Three of the four reported a feeling of light-headedness. The Flanagan tests given during exposure and the Rhomberg tests given immediately after exposure revealed a slight but definite loss of coordination and equilibrium. Recovery appeared quite rapid—within 5-10 minutes. All electrocardiograms were normal throughout the exposure. There were no significant changes found in the following tests and determinations: Cephalin-floculation, thymol turbidity, urinary urobilinogen, complete urinalysis, serum iron, serum glutamic-pyruvic transaminase, serum glutamic-oxalacetic transaminase, hemoglobin, sedimentation rate and red, white and differential blood counts.
1900 (1740-2180)	5	Very noticeable odor. Obvious disturbance of equilibrium. Rhomberg test positive.

ritation. However, prolonged contact such as in shoes, gloves or in soaked clothing could result in a burn. Evidence presented shows that there should be no problem of systemic effects from absorption through the skin in anticipated industrial use.

VAPOR EXPOSURE

The information previously obtained together with the new data presented herein are summarized graphically in Figure 2 in which the results of exposures to various concentrations and times are plotted on log-log coordinates. Because of the demonstrated similarity in response with the uninhibited and inhibited materials the data from both materials are plotted on the same chart.

Data reported in the present work is closely correlated with that previously published. Rats have been shown to tolerate 10,000 ppm for 0.5 hour daily with no organic injury, Point G. The line GH which represents repeated exposure which can be expected to cause no organic injury to rats is seen to fall but slightly below that causing no injury from single exposure.

Male and female rats, rabbits, guinea pigs and female monkeys were exposed repeatedly seven hours per day to 500 ppm for six months with no detectable injury, Point K.

Exposures to 1000 ppm for 0.6 hour per day caused no organic injury, Point J, and exposure of 1.2 hours per day caused only a very slight response in guinea pigs exposed repeatedly for three months, Point L. Exposures to 2000 ppm for 0.1 hour per day caused no detectable or-

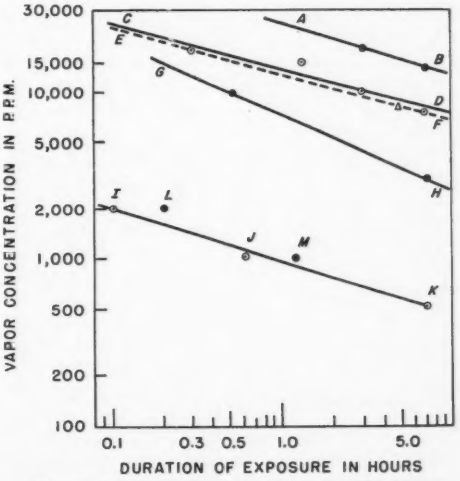

FIGURE 2. Vapor Toxicity of 1,1,1-Trichloroethane. Line AB represents the intensities of single exposures permitting 50 per cent survival of rats. Line CD represents the most severe intensities of single exposures permitting survival of all rats. Line EF represents maximum intensities of single exposures producing no histopathological changes in rats. Conditions found to cause no organic injury to guinea pigs on repeated exposure are indicated by I, J, and K. Point K also applies to all animals studied; rats, guinea pigs, rabbits, and monkeys. Line GH represents the maximum intensities of repeated exposures causing no organic injury to rats. Point H applies also to repeated exposures of monkeys.

ganic injury, Point I, and 0.2 hour per day a very slight response, Point M.

The presence of slight lung and liver pathology in the guinea pigs exposed repeatedly to 1000 ppm for either 3.0 or 1.2 hours per day and 2000 ppm for either 1.0 or 0.5 hour per day does not appear to be consistent with the data previously published. The earlier study reported no pathological changes after three months of repeated daily exposures to 1500 ppm seven hours per day. Although no cause which adequately explains the difference in results is readily apparent, the use of the most sensitive species as the criteria for establishing safe levels for human subjects seems appropriate.

A line can be drawn through I, J, K which represents conditions of repeated exposure causing no injury to guinea pigs, the most sensitive of the species tested. This line is considerably below that representing conditions found to cause no injury to rats. Therefore, recommendations based on levels causing no injury to guinea pigs can be assumed to provide an adequate margin of safety for humans.

In measuring subjective symptoms, loss of equilibrium and coordination, useful information was obtained in experiments in which humans were subjected to single exposures at known concentrations of inhibited 1,1,1-trichloroethane. Insofar as direct comparison is possible, the data obtained on human subjects are in agreement with the animal data. No evidence of systemic injury was found from exposures ranging from 500 ppm for seven hours to 1900 ppm for five minutes. Tests showed no disturbance of equilibrium or co-ordination and no subjective symptoms resulted from a seven-hour exposure to 500 ppm. A one-hour exposure to 900–1000 ppm resulted in very slight incoordination and very slight loss of equilibrium as judged by the Flanagan and Rhomberg tests.

On the basis of animal and human data it seems appropriate to suggest an Industrial Hygiene Standard (Threshold Limit, or Maximum Allowable Concentration) of 500 ppm for a seven- to eight-hour daily exposure for Chlorothene as well as for the uninhibited 1,1,1-trichloroethane when this value is defined as the concentration below which practically all results of analyses of workroom air must fall.

This material has been shown to be one of the least toxic of the chlorinated hydrocarbons. It is in the same range of toxicity as methylene chloride, appreciably less toxic than carbon tetrachloride. The vapors have a weak anesthetic action and but very little capacity to cause organic injury. Organic injury is not likely to occur in the absence of demonstrable anesthesia. In light cases of anesthesia the hazard is from incoordination and poor judgment rather than organic injury. Any adverse effect short of death due to exposure to the material should be readily reversible.

It should be noted that 1,1,1-trichloroethane is known to sensitize the heart to epinephrine[22] in a manner similar to that seen with cyclopropane, trichloroethylene, chloroform, benzene, gasoline, xylene, toluene[23] and many other solvents. In treating individuals overcome with solvents, precautions should be taken to prevent an increase in epinephrine in the blood stream. Thus, overexertion, excitement, and the administration of epinephrine should be carefully avoided.

Precautions for Safe Handling

A discussion of handling precautions associated with particular types of industrial operations has been previously presented,[24] and the conclusions presented therein are not altered by the additional toxicological data. For more general use the following precautions are recommended.

Ingestion

There should be no hazard from swallowing in ordinary industrial operations. However, the swallowing of substantial quantities such as might occur accidentally or willfully could result in illness. Containers should be properly labeled so that ingestion due to mistaken identity will not occur.

Eye contact

It is advisable to protect the eyes when likelihood of contact with the liquid exists. Safety glasses, preferably with side shields, or a face shield are recommended to prevent the pain and discomfort resulting from getting the material in the eye. If the material gets into the eyes they should be flushed thoroughly with large amounts of water and medical attention should be obtained.

Skin contact

This material presents no practical hazard from the standpoint of skin absorption and can be expected to cause dermatitis only in instances where exposure is extensive (prolonged or frequently repeated). Prolonged contact with contaminated clothing should be avoided. If substantial quantities of the material are spilled on the person, contaminated shoes and clothing should be removed promptly and not worn again until free of all solvent.

VAPOR INHALATION

The vapor concentration in the workroom air should be maintained below 500 ppm when handling either the inhibited or the uninhibited product. In order to avoid possible impairment of judgement and coordination, it would seem wise to limit exposure to concentrations approaching 1000 ppm to no more than a few minutes at a time. If a person should show ill effects that might be due to breathing the vapors he should go, or be removed, to fresh air at once. If overcome by the vapors the individual should be removed to fresh air and medical attention should be secured. If breathing stops, artificial respiration should be given. Epinephrine should never be given to a person overcome with chlorinated hydrocarbon because of the possibility of inducing ventricular fibrillation.

Practical Industrial Experience

Experience gained over the past four years during which the material has been commerically available has yielded useful information regarding the hazards presented by the commerical product. Despite its wide use as a bucket solvent only a few cases of skin irritation, typical of that caused by fat solvents, have come to our attention. No cases of eye irritation have been reported. When used with adequate ventilation no injuries due to inhalation have occurred, however, use in confined spaces has resulted in varying degrees of anesthesia. Two cases in which individuals have died as a result of over-exposure to 1,1,1-trichloroethane have been reported to us. In both cases exposure was to very high concentrations in unventilated tanks.

Four other instances in which people have been ill or even overcome in high concentrations in confined areas have been called to our attention. In each case the individuals were removed and quickly recovered without any after effects being noted.

In view of the extensive commerical use, this is considered to be very favorable experience and tends to justify the extrapolation of the laboratory data obtained on experimental animals to human subjects.

Summary

1,1,1-Trichloroethane was tested both as the uninhibited solvent and as a commercially available inhibited solvent, Chlorothene. The acute toxicities of the two materials were shown to be essentially the same.

The administration of single oral doses of 1,1,1-trichloroethane yielded LD_{50}'s for laboratory animals ranging from 5.6 gm/kg for rabbits to 12.9 gm/kg for rats. The material was shown to cause slight transitory irritation in the eyes with little likelihood of permanent injury. The toxicity from skin absorption was found to be low, doses of 4 gm/kg failed to kill any rabbits exposed for 24 hours. Repeated multiple daily applications of 500 mg/kg to the skin of rabbits caused no effect other than reversible local irritation.

Laboratory animals were exposed repeatedly to 500, 1000, 2000 and 10,000 ppm in order to establish conditions safe for repeated exposure. Rats, guinea pigs, rabbits and monkeys were unaffected after six months of repeated seven-hour exposures five days per week to 500 ppm. Female guinea pigs which were found to be the most sensitive in previous experiments were able to tolerate 1,000 ppm for 0.6 hour per day for three months and 2000 ppm for 0.1 hour per day with no detectable adverse effects. Male rats tolerated exposure of 0.5 hour per day to 10,000 ppm with no organic injury. The effects of the material have been shown to be primarily anesthesia with only slight capacity to cause reversible injury to the lungs and liver. The results of exposures of humans are reported.

A standard for evaluating regular seven-to eight-hour daily exposures is defined as the concentration below which practically all results of analyses of workroom air must fall. The value of 500 ppm is suggested as this standard for Chlorothene as well as for uninhibited 1,1,1-trichloroethane. Concentrations approaching 1000 ppm are known to cause anesthetic effects and should be avoided. Precautions for safe handling are suggested.

Industrial experience gained to August 1, 1958 is discussed.

Acknowledgments

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Scientific Exhibits

APPLICATIONS are being solicited now for Scientific Exhibits for the 1959 Industrial Health Conference to be held in Chicago, Illinois. Exhibits will be shown from April 28 through April 30. We are all interested in having a number of high quality exhibits. Those intending or desiring to offer exhibits are urged to make application for space as soon as possible. Application forms and further details of information may be secured from D. P. O'Neil, Chairman of Scientific Exhibits Committee, Argonne National Laboratory, P.O. Box 299, Lemont, Illinois.

Nuclear Congress

PRELIMINARY PLANS for the Fifth Nuclear Congress to be held in Cleveland, Ohio, April 5–10, 1959, have been announced by the Engineers Joint Council. As in the past the Congress will be composed of four parts: The Nuclear Engineering & Science Conference, the Hot Laboratories & Equipment Conference, the Atomic Energy Management Conference and the Atomfair at which nuclear equipment will be on display. The Congress will be held at the Cleveland Auditorium. A list of sponsoring societies and other detailed information may be obtained by writing to Nuclear Congress, c/o Engineers Joint Council, 29 West 39th Street, New York 18, New York.

The Effects of Air Pollution on Human Health*

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Introduction

DURING THE past decade the problem of the effects of oxidant and reducing types of smog on the health of man has become one of increasing interest. This paper is concerned only with the effects of reducing fog, since the pilot studies carried out by our group have been directed mainly towards the effects of air pollution on human health in coal-burning cities.

In general, there are two ways in which the effect of reducing smog on man may be ascertained:

(*1*) *Studies of acute exposures in industry or in catastrophic episodes of urban air pollution.* Industrial exposures[1, 2] are usually associated with abnormally high in-plant concentrations of a known material or compound, and are followed by well-defined clinical reactions. Retrospective investigations are relatively simple since the population at risk, and the number actually affected, can usually be obtained with accuracy. Even more important, the chemical involved and its approximate concentration are usually known. In catastrophic episodes, such as occurred in the Meuse Valley,[3] in Donora,[4] and in London,[5, 6, 7] investigation is complicated by the fact that the effects may be due to one or several of many atmospheric pollutants, and that calculation of attack rates is exceedingly difficult since there may be great difficulties in deciding whether specific cases of sickness or death can be directly attributed to the smog. Sickness is not an unusual event and may not be recorded unless the patient has to be hospitalized. Morbidity statistics of acute urban smog are, at best, difficult to obtain, and even then are probably unreliable.

Death occurs only once, and can be recorded precisely in time. Legal requirements that all deaths be reported to a central authority enable mortality rates to be calculated with greater precision. Even if the medical diagnosis is in doubt, the excess of deaths occurring during a foggy period over that expected to occur in a similar time period without the presence of smog is a rough but reliable indication of the lethal effects of air pollution on man. However, the increasing use of antibiotics and cardiac drugs may alter the picture. Persons affected by air pollution may recover from their pneumonia or heart failure and die later from some cause not apparently attributable to immediate air pollution, even though the primary cause of death may have been initiated by a previous acute exposure to smog. The occurrence of such "delayed deaths" will tend to obscure the true mortality due to the effects of any one acute smog.

(*2*) *Studies of chronic exposures.* When air contamination is well controlled in a city, or when the levels of pollution are low (for example in uncontrolled suburban or rural areas) the problem of relating air pollution to human disease becomes very difficult. Allowance must be made for man's power of adaptation to chemical injury, and the course of his future health depends upon the resultant of two opposing forces—first, the duration and intensity of the exposure and second, the power of the defensive mechanisms of the body to oppose or to repair that injury. Man may recover with so slight a degree of bodily damage that physical disability is not evident even with the most searching clinical examination. More sensitive techniques of examination, (for example carbon monoxide diffusion) may, however, suggest that damage has occurred, and repeated exposure to similar smog

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insults over many years may produce a summation of injury and physical disability which is clearly evident both to the patient and to the clinician. The increased incidence of chronic bronchitis and emphysema in areas of high air pollution may well be due to this process of summation of innumerable small pulmonary insults. The picture may be complicated by other competing causes, such as cigarette smoking or adverse industrial environments, but the process remains essentially the same—the balance of forces between man's external environment and the ability of the body to adjust to it or defend itself against it.[8, 9, 10]

Recent medical advances, such as antibiotics, cardiac drugs, and physiotherapy afford a means of strengthening the natural defences of the body against an adverse environment. Patients may survive repeated smog episodes at the cost of increased cardio-respiratory disability. Acute heart failure is prevented by drug therapy, but the damage to lung tissue is cumulative and irreversible. Thus, a "susceptible" population of old people is produced who may be confined to homes or hospitals with increasing degrees of breathlessness, and even mental confusion resulting from cerebral anoxia.

Accordingly we have developed air hygiene studies directed primarily towards: (1) ascertaining whether the acute reaction of man to variations in low level urban air pollution can be measured and described by periodically measuring lung function; (2) the development of more sensitive and objective tests of lung function which can be used in the field; (3) the development of statistical and epidemiological techniques, which could be used on future large-scale prospective surveys of the effects of long-term low-level air pollution on man.[11]

During 1955–56 three pilot studies were undertaken in Cincinnati and all field work has been completed. This paper gives preliminary results only of the third survey. The final conclusions must await completion of the statistical studies.

Plan of the Study

Cardio-respiratory cripples were selected since they were thought to be more susceptible than healthy individuals to the effects of smog, and because, as a group, they tend to remain in the vicinity of their own homes in which air pollution measurements are being continuously recorded. Each was visited three times a week by a nurse who obtained the necessary clinical and environmental measurements. Outdoor air sampling stations were placed at three different areas of the town and serviced by a technician.

Three sets of data were obtained in respect to each patient and may be described as: (1) measurement of his complaints, (2) measurement of his reactions, and (3) measurement of his environment.

Measurements of Man's Complaints

Each patient was asked to complete a diary sheet six-hourly in response to specific questions regarding his feeling of well-being in respect of symptoms such as shortness of breath, coughing, wheezing, etc. (Figure 1). The diary sheets were collected and examined by the nurse at each visit and the responses graded numerically in respect of severity and compared with corresponding levels of air pollution.

This diary technique produces useful data in all cases during the first month or six-weeks of a survey. After that the less enthusiastic patients (40% of total) tend to consider their answers less carefully and their diaries are then of questionable value. The remaining 60% of patients record their answers carefully and accurately for periods of over three months.

Measurement of Man's Reaction (*Lung function testing*)

At each visit a series of lung function tests were carried out. In the case of the third survey these included:

(a) Maximum Inspiratory and Expiratory Pressures (Figure 2) measured by having the patient blow into a mouthpiece connected to a modified aneroid gage. This test was used in all three surveys but is of limited value because of an uncertain theoretical basis and also because results depend upon the willingness of the patient to withstand unpleasant sensations during a maximum breathing effort.

(b) Timed Vital Capacity (Figure 3) was measured with a portable bellows spirometer developed in 1955 to overcome the difficulty experienced in the first survey of using water-filled spirometers in the field. The total volume of air obtained in a maximal forced expiration is collected in a rubber bellows. A Gaensler timer records both the total volume of air and the volume obtained during the first one, two, or three seconds of the expiration. The ratio of timed to total volume is reduced if there is airway obstruction, for example bronchoconstriction due to pulmonary irritants. This test of lung mechanics, like that for pulmonary pressures, depends partly on patient motivation and may become less objective when repeated frequently, as is necessary for field studies.

(c) Carbon Monoxide Diffusion (Figure 4) is

AIR POLLUTION SURVEY 1956
PATIENT DIARY

Date..... Day..... Patient's No.....

		12–6 A.M.	6–12 A.M.	12–6 P.M.	6–12 P.M.
Cough	Less than usual				
	Usual amount				
	More than usual				
Short of Breath	Less than usual				
	Usual amount				
	More than usual				
Sputum	Less than usual				
	Usual amount				
	More than usual				
Wheezing	Less than usual				
	Usual amount				
	More than usual				
Chest Pain					
Running Nose					
Sore Throat					
Headache					

Away from home:

Where? ..... When? ..... How Long? .....

....

....

House-cleaning

Date:..... Time:.....

Cooking involving frying or oven-roasting

Date:..... Time:.....

Medicines

Remarks

FIGURE 1. Patient Diary Sheet

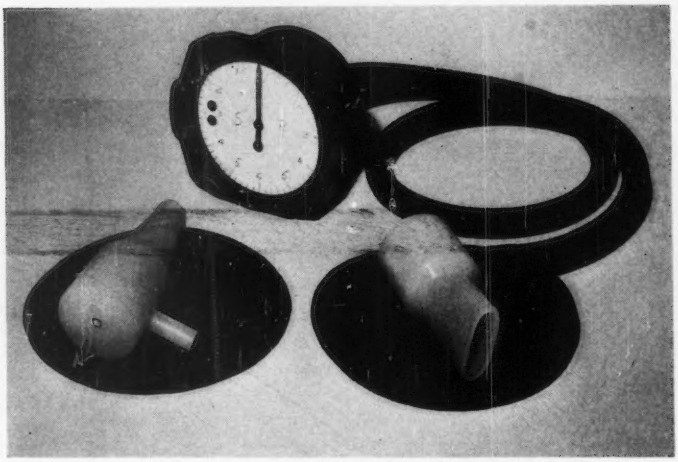

FIGURE 2. Inspiratory and Expiratory Pressure Gage

FIGURE 3. Portable Bellows Spirometer

measured by the portable box-bag,[13, 14] and measures a different aspect of lung function—that of the ability of the alveolar-capillary membrane to exchange respirable gases with the blood. A known volume of air containing a "tracer" gas (0.1% carbon monoxide) is breathed by the patient and exhaled into a collecting bag. The test takes about one minute and is timed with a stopwatch. The concentrations of carbon monoxide in the inspired and expired air are found by infrared analysis, and the amount of carbon monoxide taken up by the blood per minute is calculated. Damage of the alveolar-capillary membrane, due for example to pulmonary irritants, is indicated by impaired diffusion and decreased carbon monoxide uptake. One possible limitation to this test is that carbon monoxide uptake may also be affected by un-

equal ventilation and blood flow in different parts of the lung. This limitation can now be overcome by using the technique of Partitional Respirometry which has recently been developed by our group. However, even in its original form the portable box-bag has proved to be a very satisfactory test for field survey use.

Measurement of the Environment

Hourly measurements of smoke, temperature and humidity were taken at outdoor stations and also within homes of patients in all three surveys using A.I.S.I. (Hemeon) sequence smoke samplers and thermo-hygrographs[15] (Figure 5). Wilson sequence samplers were used to obtain hourly values of total gaseous acid at the outdoor stations in all surveys, but indoor sampling of gaseous acid was done only during the third survey after a midget sequence sampler had been developed for domestic use[16] (Figure 6).

Sampling equipment used in the home was enclosed in soundproof cabinets and maintenance was done essentially by nurses. Outdoor equipment was housed in weather-proof cabinets and the stations were maintained by a technician.

There were substantial differences between outdoor and indoor measurements of smoke and gaseous acid. Outdoor smoke for the entire third survey (Oct. 2 to Dec. 17, 1956) averaged 3.8 coh units per 1000 linear feet compared to a mean value for all patients of 2.1 coh units per 1000 linear feet indoors. Corresponding average values for total gaseous acid were 0.047 ppm outdoors and 0.024 ppm indoors. Comparison of indoor smoke values showed that some patients were subjected to higher average concentrations than others, even when they live in the same institution. This is probably related to habits of keeping windows open or closed. For example, in one home for old persons the average suspended particulate matter in the men's ward was 15% higher than in the women's ward. The men tended to keep their windows open whilst the women disliked draughts and kept their windows shut.

Lowest concentrations of domestic smoke occur between mid-day and 6 p.m., whilst concentrations between 6 p.m. and midnight and midnight and 6 a.m. are about 2.5 times the afternoon values. The period 6 a.m. to mid-day is that of highest average smoke concentration, indoor values being 3.5 times the afternoon values with very high hourly peaks between 6 a.m. and 9 a.m.

Domestic temperatures tend to show little variation within the range 70° to 80°F, due to central heating, although outdoor temperatures vary considerably with the weather. Indoor relative humidity fluctuates widely according to outdoor conditions and with domestic heating and ventilating arrangements. Temperature and humidity measurements have been included in the multiple regression analysis but it is still

Figure 4. Portable Box-bag for CO Diffusion Test

Figure 5. Smoke Sampler and Thermohygrograph in cabinet for domestic use.

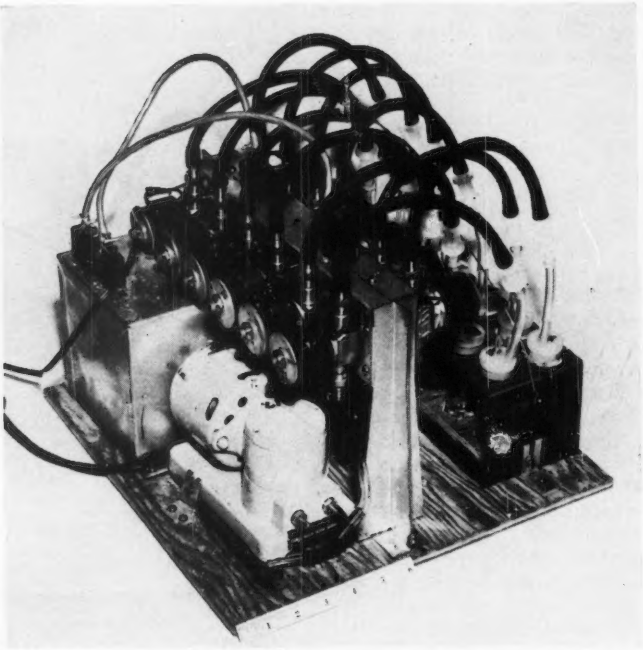

FIGURE 6. Midget Sequential Sampler for Gaseous Acids

too early to say what effect they have on the other environmental and clinical measurements.

Results

About 110,000 observations of environmental conditions and patient reactions were obtained during the three-month period of the third survey. Multiple regression analysis of these data is about 50% complete. Another year will be required before final conclusions can be drawn. In the case of the first and second surveys, the volume of data is so great (about 500,000 observations in all) that it has not been possible so far to analyze the data by multiple regression.

The results now to be given are preliminary findings only and these conclusions may have to be modified when the analysis is completed.

During the period October 1 through December 17, 1956, average daily indoor smoke values 50% or more in excess of mean values were experienced during the periods October 12 to 17, and November 18 to 20 (Figure 7). One day of very high smoke (150% in excess of normal) was experienced on December 4. Taken as a group, the patients appear to have reacted significantly to the October and to the December episodes, although their reactions to the November episode are mixed. Patient responses were demonstrated most clearly by the carbon monoxide uptake test, although in the October episode, six of the ten patients also showed an increase in symptoms commencing five to six days after the first peak of smoke in their homes. The increase in symptoms was not so marked during the December episode, but this may be related to the fact that some of the patients were becoming tired of keeping accurate records of their symptoms.

In both the October and December episodes the most striking feature seems to be a prolonged fall in carbon monoxide uptake commencing about five days after the peak of air pollution and persisting for about a week at levels which deviated from the mean CO uptake for the entire survey by 1.0 to 1.5 standard deviations. If the fall in CO uptake during the October episode is compared to the mean CO uptake for that month only, the standard deviation reaches 2.7. Much more work will be required to evaluate these changes in CO uptake. It is probable that individual patients have different time lags in their response to peaks of air pollution, so that the response curve for all patients is only a first approximation to the actual response of any one patient. There is

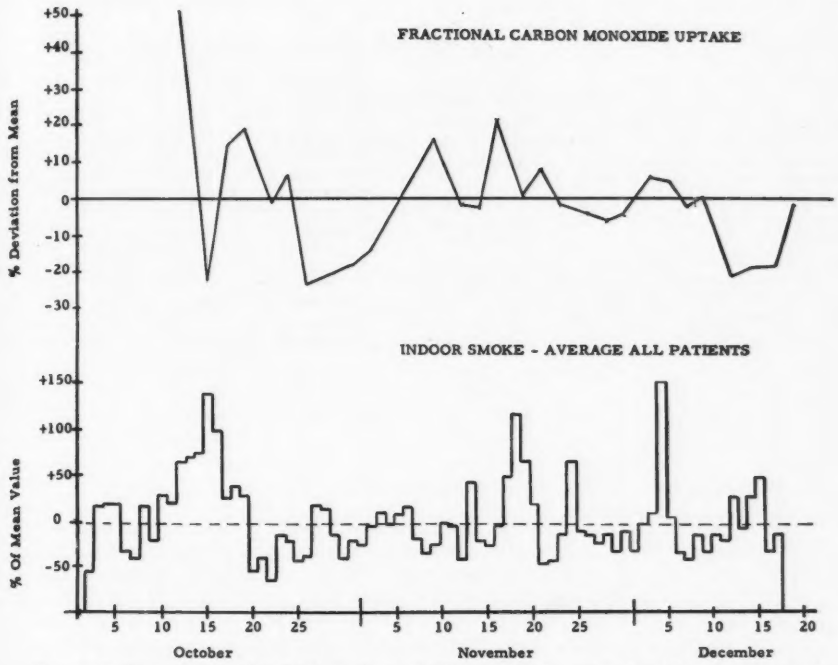

FIGURE 7. Comparison of indoor smoke and CO uptake (mean values for ten patients) Oct.–Dec. 1956.

also some evidence to suggest that after a peak of air pollution the individual patient shows an immediate fall in CO uptake within 24 hours, and a brief period of compensation follows before the delayed reaction occurs.

Measurements of timed vital capacity and of pulmonary pressures do not show clearly defined changes in the patients considered as a group. Some patients show large changes on isolated days, but the changes are not clearly associated with peaks of air pollution, and may be due to other factors such as patient motivation. However, multiple regression analysis suggests that significant changes occur in some individual patients when related to combinations of smoke, temperature and humidity. It also may be that the patients did have some bronchoconstriction following peaks of air pollution, as evidenced by symptoms of wheezing, but that they had recovered from this transient effect before timed vital capacity tests were carried out.

Although these preliminary results may give some encouragement to the clinician in his search for the causation of disease, the implications which follow do not give cause for complacency. The human reactions which have been observed occurred in a city in which air hygiene is well controlled. At the same time, improvements in medical treatment are producing an increase in the span of human life. In an aging population there will be an increasing proportion of people who are unduly susceptible to smog because of their decreased cardio-pulmonary reserves. If air hygiene controls were to be relaxed, or if another acute smog episode of the Donora type were to be imposed upon such an aging population in any similar industrial city, a very great increase in deaths of older people would follow. This, then, is the problem which confronts both industrial hygienists and the medical profession, and whose solution concerns us all.

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A New Journal

THE INDUSTRIAL Medical Association will begin publication of their new, official periodical in January 1959 under the name, *Journal of Occupational Medicine.* It will appear monthly under the editorship of Adolph G. Kammer, M.D., a past president of the Industrial Medical Association and Head of the Department of Occupational Health, Graduate School of Public Health, University of Pittsburgh.

The Journal of Occupational Medicine will be owned and controlled by the Industrial Medical Association and will be published by Wiesen-Hart, Inc., 420 Commercial Square, Cincinnati 2, Ohio. Inquiries regarding subscriptions and other business matters should be addressed to Mr. Clark D. Bridges, Publication Manager, Industrial Medical Association, 28 East Jackson Boulevard, Chicago 4, Illinois. Articles submitted for publication should be sent direct to Dr. Kammer at 2057 Beechwood Boulevard, Pittsburgh 17, Pennsylvania.

Analytical Abstracts

ANALYTICAL ABSTRACTS was first published in January 1954 by the Society for Analytical Chemistry on cessation of publication of *British Abstracts C, Analysis and Apparatus.* The newer journal covers the analytical chemistry literature of the world and contains upwards of 4000 abstracts annually. Abstracts are prepared by experts in the several fields and often by chemists in the country of publication of the original paper.

The subscription rate for *Analytical Abstracts* for 1959 is $14.00 postage-free including index. With *The Analyst* included the rate is $23.52 for the year. Some back issues are available. The *Analytical Abstracts* is also available printed on one side of the paper suitable for clipping and filing. The price per annum, $15.05 without index and $18.48 with index for this special printing.

Inquiries or subscriptions should be sent to The Secretary, The Society for Analytical Chemistry, 14 Belgrave Square, London S.W. 1, England.

The Relationship Between Sulfur Dioxide and Particulate Matter in the Atmosphere*

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A PROGRAM for the sampling and analysis of selected air pollutants, sequentially or continuously, throughout the day and night, at two stations in Cincinnati was initiated in January of 1957, and is now in its second year.† The purpose of this aerometric survey was to study the relationships between the selected pollutants in the natural photochemical formation of the "oxidant" type of smog.[1, 2]

It is generally recognized that the pollution of the atmosphere differs in different areas, and that the problems due to air pollution vary, in greater or lesser degree, from community to community. These problems are dynamic in character since they undergo continual change in association with the types and quantities of fuels being used and with change in the activities in metropolitan areas. In communities where coal is the principal fuel, sulfur dioxide and air-borne particulate matter have long been considered important indices of air pollution, and more measurements have been made of these pollutants than of any other. Since sulfur dioxide and particulate matter were among the contaminants selected for investigation in Cincinnati, the findings obtained in this survey permit interesting comparisons with those obtained in earlier surveys.[3, 4] This paper, therefore, will describe the features and the patterns of occurrence of these two pollutants, as they have been observed in Cincinnati since 1946.

Procedures

Comparisons are made of the results obtained at two sampling sites—Station 1 in the midst of the commercial center in the basin of the city, and Station 2, in a residential area practically in the center of metropolitan Cincinnati. The latter could be expected to represent fairly general atmospheric conditions, rather than the extremes associated with rural or industrial sites. Each site was equipped with recorders for the continuous determination of the concentrations of nitrogen dioxide and oxidant, a sequential sampler for determining the concentration of sulfur dioxide in the air during each period of 2 hours consecutively, night and day, and equipment to collect two types of particulate matter throughout each day. One type of the particulate matter was that removed over each period of 24 hours from approximately 2000 cubic meters of air aspirated through a glass-fiber filter mat in a high-volume sampler. The second type consisted of that deposited on the paper tape of an A.I.S.I. smoke sampler during successive 2-hour periods. This equipment and other accessory apparatus, will be described, along with the various analytical procedures, in a separate paper.

Results and Discussion

Records from the Bureau of Air Pollution Control of the City of Cincinnati were used to prepare the plot in Figure 1, which shows the average yearly deposition of solid particles at the two stations in Cincinnati since 1946. As may be seen, there has been a steady decrease in the amount of such deposits in the business area (Station 1), the current levels being approximately 50 per cent of those in 1946. The decrease in the residential area has not been so great as in the basin of the city, but the trend, though slight, is downward.

The quartile levels of the concentration of air-borne particulate matter, as determined in various surveys and expressed in milligrams per cubic meter of air, are recorded in Table I. The decreases in concentration were marked, the median concentration at Station 2 in 1957 being only 40 per cent of that found during the period 1946–1951. At Station 1, the median

* Presented at Nineteenth Annual Meeting of American Industrial Hygiene Association at Atlantic City, New Jersey, April 24, 1958.

† This investigation supported in part by a grant from the U. S. Public Health Service.

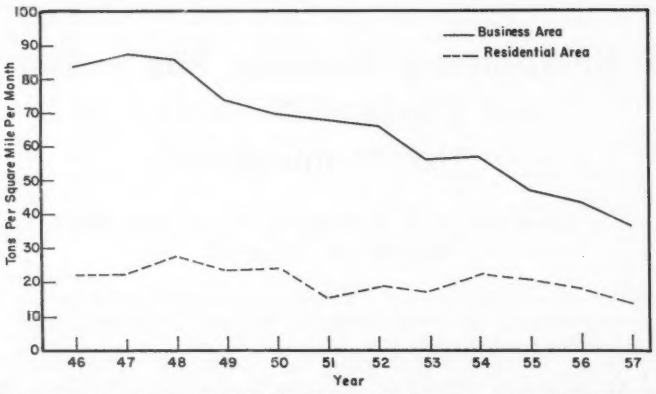

FIGURE 1. Average yearly soot-fall in Cincinnati during period 1946–1957 (Cincinnati Bureau of Air Pollution Control).

TABLE I

Quartile Concentrations of Particulate Matter in Milligrams Per Cubic Meter as Observed at Two Stations in Cincinnati, Ohio in the Course of Various Surveys

Site	Year	25%	50%	75%	Range
Station 1 (Business Area)	1946–51	0.30	0.40	0.60	0.13–1.23
	1955	0.26	0.33	0.40	0.18–0.56
	1957	0.17	0.21	0.25	0.11–0.37
Station 2 (Residential Area)	1946–51	0.18	0.25	0.32	0.04–0.88
	1955–56	0.06	0.11	0.15	0.04–0.30
	1957	0.07	0.10	0.14	0.04–0.41

TABLE II

Quartile Concentrations of Sulfur Dioxide in Parts Per Million as Observed at Two Stations In Cincinnati, Ohio in the Course of Various Surveys

Site	Year	25%	50%	75%	Range
Station 1 (Business Area)	1946–51	0.046	0.056	0.175	0.008–0.463
	1957	0.009	0.018	0.033	0.001–0.281
Station 2 (Residential Area)	1946–51	0.014	0.032	0.067	0.003–0.272
	1955–56	0.013	0.025	0.044	0.001–0.250
	1957	0.008	0.017	0.025	0.001–0.200

concentration in 1957 was approximately 50 per cent lower than it was in the period 1946–1951. In general, the minimum and maximum levels of concentration were lower during the 1957 survey than they were during earlier surveys.

TABLE III

Quartile Concentrations of Sulfur Dioxide in Parts Per Million as Observed During Daylight Hours Only at Two Stations in Cincinnati, Ohio in the Course of Various Surveys

Site	Year	25%	50%	75%	Range
Station 1 (Business Area)	1946–51	0.046	0.056	0.175	0.008–0.463
	1957	0.010	0.021	0.041	0.001–0.281
Station 2 (Residential Area)	1946–51	0.014	0.032	0.067	0.003–0.272
	1957	0.007	0.015	0.023	0.001–0.200

The levels of concentration of sulfur dioxide in the air during the various periods of investigation are compared in Table II. Here too, the concentration decreased. Although the values for the period 1946–1951 are not strictly comparable to those obtained after 1955 (the latter were based on continuous sampling throughout the night and day, while those of the 1946–1951 period were obtained by the analysis of individual samples collected between 8:30 a.m. and 5:00 p.m.) the relationships are not altered when the data for the daylight hours only are compared, as in Table III. The median concentrations during 1957 were 62 per cent and 53 per cent of those found at Stations 1 and 2, respectively, during the period 1946–1951. Significant decreases in all of the quartile groupings of concentrations have occurred with the passage of time.

These or comparable improvements in the cleanliness of the atmosphere have occurred elsewhere, no doubt. In Cincinnati they have resulted from a combination of factors, includ-

ing a stricter enforcement of smoke abatement regulations, restrictions in the use of certain types of solid fuels, more general employment of efficient combustion equipment, more and better removal of effluents from the stacks and vents of industry, the partial elimination of open-dump fires, and reduction in the numbers of open-fire heating units through the razing of substandard dwellings in slum clearance projects. The increasing use of petroleum as fuel for locomotives, and of petroleum and natural gas as fuels for domestic heating and as industrial sources of power and heat, has also exerted its influence. From the aspect of cleanliness, the change since the war has been apparent to the ordinary observer not only through the improvement in general visibility but also in the fact that the previously frequent occurrences of dense admixtures of smoke and fog have been seen only once or twice during the past ten years.

The data obtained during the survey in 1957, when scanned, appeared to indicate that a relationship existed between the air-borne particulate matter and the concentration of sulfur dioxide, and to suggest that both were derived from the combustion of solid fuel. Figure 2 gives the average hourly concentration of sulfur dioxide, and the light-scattering potential of the solid particles suspended in the air during the heating season. These particles are also associated with the soiling potential of the air (particularly atmospheric smoke) which is usually expressed as coh units/1000 feet, as described by Hemeon, Haines and Ide.[5] As may be seen, the patterns of the coh values and the concentrations of sulfur dioxide show distinct peaks. In the case of the residential area (Station 2), the curves of each contaminant show two distinct peaks, one at 7:00 a.m. and a lesser one at 11:00 p.m. The increase in concentration may be attributed in part to meteorological conditions (low wind speeds and inversions) and in part to domestic and industrial activity, particularly to the increased demand for heat and power. In the case of the business area, each curve (sulfur dioxide and coh value) shows but one distinct peak, that of sulfur dioxide lagging about four hours behind the maximum coh value. The maximum concentration of light-scattering particles (coh values) is reached at the same time at the two stations, while the maximum concentration of sulfur dioxide in the business area occurs at 11:00 a.m. instead of at 7:00 a.m. as was the case in the residential area. Moreover, in the business area, the concentration of sulfur dioxide is lowest during the night and early morning

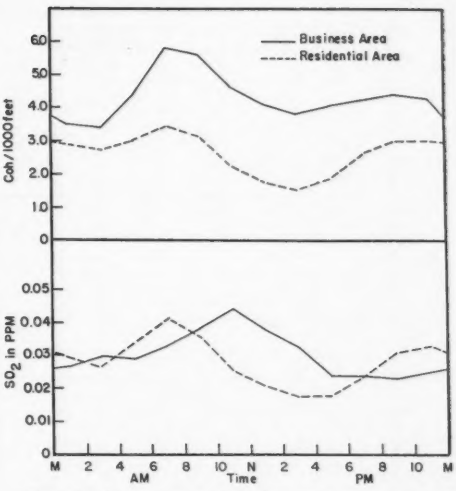

FIGURE 2. Average hourly concentrations of sulfur dioxide and coh values during the heating season of 1957.

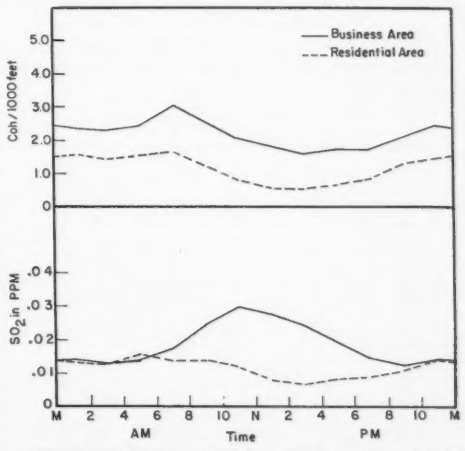

FIGURE 3. Average hourly concentrations of sulfur dioxide and coh values during the spring and summer seasons of 1957.

hours, while in the residential area, the lowest concentration of sulfur dioxide and coh values are found to occur during the period between 2:00 p.m. and 6:00 p.m., in general dependence upon the strength of the air currents.

Figure 3 gives the diurnal variations in the concentration of light-scattering solids (coh value) and of sulfur dioxide during the spring and summer seasons. At these lower levels, the curves for both contaminants are similar in

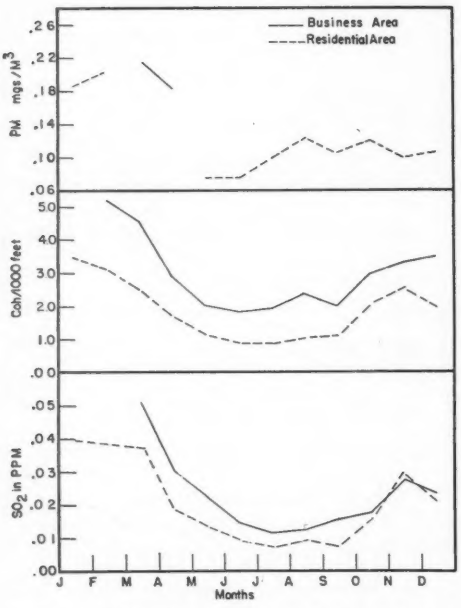

FIGURE 4. Monthly averages of the concentration of sulfur dioxide, coh values and particulate matter during 1957.

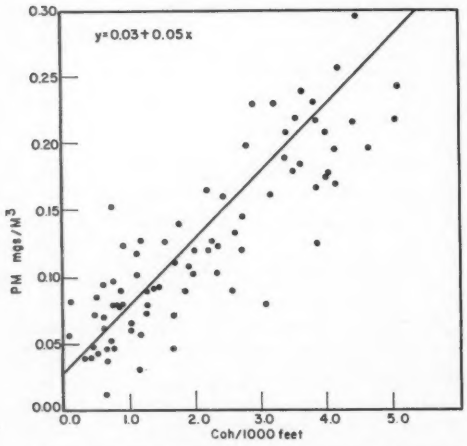

FIGURE 5. Relationship between coh values and quantity of particulate matter in the air.

shape to those observed during the heating season. As was the case during the heating season, the maximum concentration of sulfur dioxide in the business area occurred at 11:00 a.m., some four hours after the coh value had reached its maximum. The pattern of the hourly concentration of sulfur dioxide appears to depend upon the density of motor traffic during the daylight hours in the commercial areas and also upon the characteristic ventilation of canyon-like streets. In accord with this relationship, the sources of pollution in these areas seem to emit more sulfur dioxide than particulate matter.

In Figure 4 the average monthly concentration of sulfur dioxide is compared with the average monthly concentration of the two types of particulate matter collected at each station. The relationship to the heating season is shown by the dips in the curves during the six months when the need for the combustion of fuel was at its lowest level. The data relating to particulate matter (PM mg/m^3) collected by the high-volume sampler, while incomplete, suggest that the pattern shown by the curves for sulfur dioxide and the light-scattering solids (coh units) is also followed by the total air-borne particulate matter.

It is generally believed that coh units are not suitable indices of the total quantity of particulate matter in the air and it may well be true that there are situations in which they are not. However, our data indicate that there is a high degree of correlation between the two under the local conditions. Figure 5 is a scatter diagram that compares the average daily coh value with the average daily concentration of particulate matter. Data for only 81 days in the residential area were used to prepare the graph but the pattern of distribution is highly suggestive of a relationship between the coh value and the concentration of the air-borne particulate matter. The regression curve relating the coh value to the concentration of particulate matter is seen to be a straight line of positive slope. The correlation factor for this line is 0.82, a statistically significant value. It would appear, therefore, that in communities where coal is the principal fuel, the concentration of particulate matter can be calculated from the value of the coh unit. In Cincinnati, the formula, $y = 0.03 + 0.05x$, will give the milligrams of particulate matter per cubic meter of air where "x" is the observed coh value. Further testing is planned to establish the validity of this observation.

The frequency of occurrence of certain average concentrations of sulfur dioxide and the number of hours of occurrence of these concentrations are given in Figure 6. The graphs give the cumulative percentage of occurrence and the number of hours per year when certain concentrations were exceeded at the two sta-

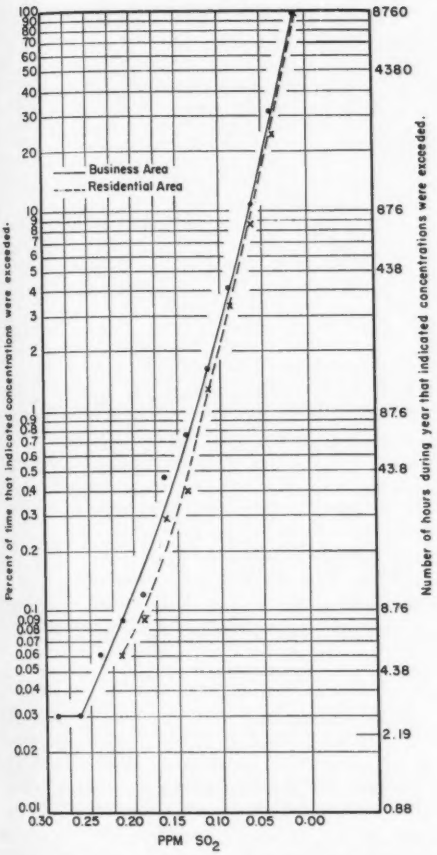
Business Area
Residential Area
Percent of time that indicated concentrations were exceeded.
Number of hours during year that indicated concentrations were exceeded.
PPM SO_2

FIGURE 6. Comparison of frequencies of occurrence of various levels of the concentration of SO_2 at two stations in Cincinnati during 1957.

tions. Higher concentrations were found in the business area, but the highest concentration, 0.28 ppm, occurred during the year only 0.03 per cent of the time, i.e. 2.63 hours. Concentrations in excess of 0.10 ppm occurred only 1.8 per cent of the time, or 158 hours. In the residential area, the highest concentration of 0.20 ppm was found only 0.06 per cent of the time (5.3 hours), while levels in excess of 0.10 ppm occurred only 1.4 per cent of the time, or 122 hours.

The values used to plot the graph in Figure 6 represent the average concentration during two-hour periods and do not show the maximum concentration during such periods. However, Figure 7 compares the averages in 147 two-hour samples with the findings in 882 samples

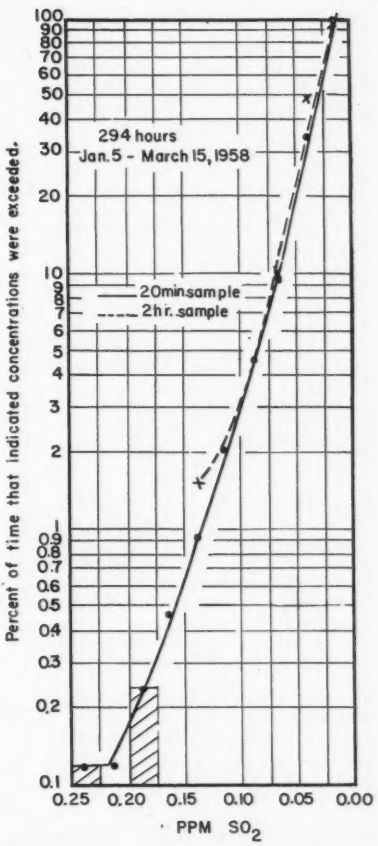
294 hours
Jan. 5 - March 15, 1958
20 min sample
2 hr. sample
Percent of time that indicated concentrations were exceeded.
PPM SO_2

FIGURE 7. Concentrations of SO_2 obtained by sampling for two-hour periods and for twenty-minute periods (continuous sequence sampling).

collected at intervals of 20 minutes during the period January 5–March 15, 1958, in the residential area. These data were obtained from samples collected at the indicated intervals within the same periods of time when the concentration of sulfur dioxide reached its peak during the hours 5:00 a.m. to 9:00 a.m. and 9:00 p.m. to 1:00 a.m. (Figure 2). It may be seen that concentrations greater than those found in the two-hour samples were exceeded in the twenty-minute samples in only 0.9 per cent of the samples, or during 7 twenty-minute periods, and that these concentrations ranged between 0.15 and 0.25 ppm. It appears, therefore, that the concentration of sulfur dioxide in the residential area did not fluctuate significantly from the average level measured during each two hours.

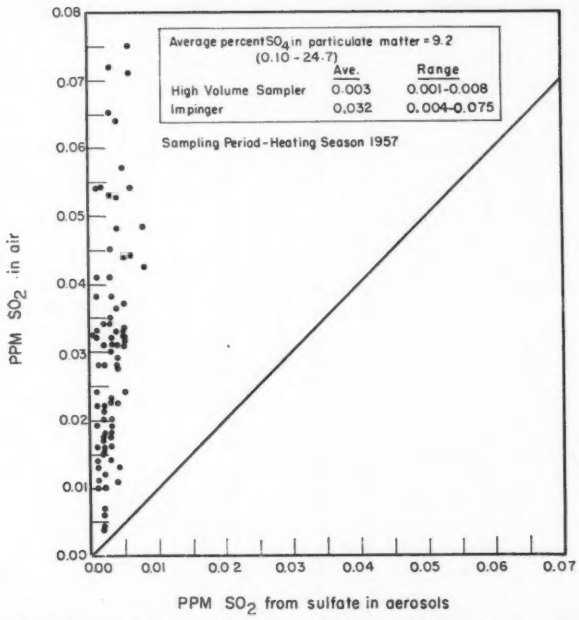
Average percent SO_4 in particulate matter = 9.2
(0.10 - 24.7)
Ave. Range
High Volume Sampler 0.003 0.001-0.008
Impinger 0.032 0.004-0.075
Sampling Period - Heating Season 1957
PPM SO_2 in air
PPM SO_2 from sulfate in aerosols
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
0.08

FIGURE 8. Total SO_2 in the air compared with SO_2 calculated from sulfate in aerosols present in one cubic meter of air.

Because of the importance of the chemical reactions taking place between particulate matter and the gaseous contaminants of the air during periods of low wind velocity and high humidity, one of the important considerations in the chemistry of air pollution is the relationship between the total gaseous contaminants and related components of the particulate matter. The irritant and harmful property of smog may well be due to the transformation of the gaseous components of the air to free acid when these gases are adsorbed on the moist surfaces of the aerosols. However, very little information is available concerning the ratio of the total acidic gaseous components, such as chlorine, sulfur dioxide, nitric oxide and nitrogen dioxide, and the chloride, nitrate and sulfate components of the aerosol particles. Junge[6] has found that the concentrations of such gases as sulfur dioxide, ammonia and the nitrogen oxides are higher than the corresponding components in the aerosols over a wide variety of geographical locations. Katz found that the ratio of sulfur dioxide to the sulfur trioxide (sulfate) in the aerosol in the vicinity of smelters was such as to indicate that 82–86 per cent was sulfur dioxide.[7]

Data obtained in Cincinnati are given in Figure 8, in which the values plotted are based on the analysis of a limited number of samples collected during the heating season of 1957. These data indicate that more than 90 per cent of the sulfurous material in the air is gaseous in character. It should be noted, however, that the samples which yielded these results were collected during periods when the meteorologic conditions were favorable for the dispersion of air pollutants. No data are available to show the relationships of total sulfur dioxide to sulfate in the aerosols during periods of weather conducive to the formation of smog. Because of the great improvement in air cleanliness that has occurred in the past few years, it may be necessary to explore these relationships under laboratory conditions.

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A Symposium

AN INTERNATIONAL Symposium on Inhaled Particles and Vapours, organized by the British Occupational Hygiene Society, will be held in Oxford in April, 1960. The Symposium will be concerned with the physical, chemical and physiological factors governing the entry of harmful substances into the body via the respiratory system. The scope envisaged is indicated by the following provisional list of topics:

Characteristics of the respiratory system affecting deposition and retention of inhaled materials; effect of changes in activity and respiration rate; variations between individuals; animals compared with man.

Deposition of particles in the respiratory system as affected by their size, shape, density and composition; behaviour of aggregates before and after deposition; volatile and hygroscopic particles; electrified particles.

Absorption of vapours in different parts of the respiratory tract; the role of condensation nuclei; mixtures of vapours and aerosols.

Natural processes of elimination from the lung; equilibria between intake and elimination rates for vapours, soluble and insoluble particles; times of residence; effect of rate of dosage.

Definition of a 'standard' respiratory system and its simulation in sampling instruments. Methods of expressing levels of atmospheric contamination.

Contributions to the Symposium will be welcomed from all countries. The main language of the Symposium will be English and it is intended to circulate the papers in advance in this language, but it is hoped to be able to provide interpretation for those oral contributions to the discussion which may have to be made in French or German. Papers submitted will be subject to scrutiny by the Society's Honorary Editor, Dr. C. N. Davies, assisted by a panel of referees.

Those wishing to contribute are requested to notify the Chairman of the Organizing Committee, Mr. W. H. Walton, Assistant Director, Mining Research Establishment, National Coal Board, Worton Hall, Worton Road, Isleworth, Middlesex, as soon as possible, indicating the subject of their papers.

Destruction of Animal and Vegetable Tissue by Combustion in the Parr Oxygen Bomb*

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THE DESTRUCTION of organic matter preparatory to chemical analysis has been one of the more vexatious problems of the analytical chemist, no matter whether he was active in the field of biochemistry, toxicology, food chemistry or agricultural chemistry. A summary of some of the difficulties encountered in the methods of dry and wet (acid) ashing has been given in a paper by Hill, *et al.*[1] While the method of alkaline wet ashing presented by the authors in the latter paper eliminates some of the drawbacks of the conventional methods, it has some handicaps of its own. Since it is slow, it does not permit the rapid accumulation of data nor does it destroy all of the organic matter of the animal tissue, but rather converts it to water soluble materials (probably largely amino acids). It is not useful for the destruction of vegetable matter, and it may not be useful if certain heavy metals are involved. For boron determinations, it still requires the subsequent tedious and cumbersome methyl borate distillation unless boron separation by ionophoresis is employed.[2]

It appeared to the senior author that the destruction of all of the organic matter in a closed system, so that no losses could occur, would be an effective and expedient method of accomplishing this difficult task. A calorimeter suggested itself as the ideal tool. In consequence, preliminary tests were made with a Parr Oxygen Bomb. These initial tests, which proved to be very successful even though considerable difficulties were encountered, were reported in an Army Chemical Corps Contract Report.[3]

The Parr Oxygen Bomb is a special alloy steel cylinder with a screw ring capable of fastening a head piece to the cylinder. The head piece carries an oxygen inlet and release valve and two heavy wires for the conduction of the electric current. The end of one of the wires is bent into the form of a loop, which holds a removable flat dish made of the same alloy steel.

In operating the equipment, the sample to be burned is placed in the dish, a piece of wire is fastened to the electrical terminals in such a manner that it either touches the sample or is imbedded in it, a few milliliters of water are placed on the bottom of the steel cylinder, the assembly is closed, the inlet valve is connected with an oxygen cylinder, and oxygen is admitted until a pressure of 25 atmospheres is reached. The assembly is then placed in a water jacket and electrical contact is made by pressing a button. This causes the wire inside the bomb to glow and ignite the organic material which burns in a matter of seconds. The gases are slowly released through the vent valve, to avoid loss of the sample, and the bomb contents are ready for analysis.

Originally, the Parr Oxygen Bomb was used primarily for the determination of the caloric value of combustible materials, such as coal, coke and oils. However, it has also found use in the determination of sulfur and halogens in these same materials as well as synthetic organic compounds. Its use has thus been restricted to certain analytical purposes. At the onset of our research, we had found no indications that it had been used for the destruction and subsequent analysis of biological materials, such as animal tissue, until our work had been substantially completed. A recent reference[4] shows parallel thinking at about the same time, but it is not readily available and has not become well known.

When first applying the Parr Oxygen Bomb to our needs for tissue destruction in preparation for boron analysis, it became obvious that modifications of the normal procedure would be necessary. Animal tissue has a high water content and does not burn well *per se*. Prior drying was not favored because of possible boron losses, particularly in cases involving the storage of boranes

* Supported by Callery Chemical Company under a contract from the Bureau of Aeronautics, Department of the Navy.

in the tissue.† The addition of a "booster fuel" served the purposes well because it provided the calories necessary to evaporate the tissue water and to initiate the combustion of the organic matter.

Initially, flaked naphthalene was mixed with the wet minced tissue and the mixture pressed into pellets in the pellet press which is auxiliary equipment for the Parr Oxygen Bomb. The lack of absorptive capacity for water of the naphthalene resulted in oozing of liquid during the pelletizing process and led to the trial of other booster fuels. Benzoic acid, which was first considered on account of its light fluffy nature, was found to be only slightly superior to naphthalene. Several paper pulp filter aids and cane sugar proved to be much better but not quite good enough because they either were supplied in sheet form, necessitating manual disintegration, or were not absorbent enough. After several trials, S & S Ash Free Analytical Filter Pulp (Fisher Scientific Company's Catalog Number 9-947) was tried and found to be just about ideal. It has tremendous water absorptive capacity, can be compressed together with tissue to form firm pellets, and contains a minimum of impurities (0.1 mg. per gram).

Safety requirements impose certain restrictions on the amount of combustible material that can be handled in the Parr Oxygen Bomb. While the manufacturer recommends that no more than 1½ grams of coal be burned, it would seem that, in view of the low caloric content of tissue as well as of the paper pulp, a total of perhaps two or three grams could be handled without much difficulty other than getting the material into the combustion cup. In the present investigation, from 0.1 to 1.0 grams of tissue with about the same amount of paper pulp has been found to be satisfactory.

Considerations other than the caloric value, such as the amount of the element to be determined and to be expected in the tissue sample may dictate the size of the sample. The tissue sample should furnish enough of the element in question so that the value falls within the best range of the particular chemical analytical method to be employed in the subsequent analysis of the bomb contents. On the other hand, enough tissue must be used to ensure selection of a reasonably representative aliquot. It is recognized that for biological materials it will rarely be perfect, even if the tissue were homogenized, unless the whole organ is utilized and care is taken that no segregation of liquid and solid phases takes place. If the content of the element in the tissue in question is so low that available methods of analysis cannot determine it with reasonable accuracy, then a measure of "concentration" is possible by burning successive batches of the tissue in the bomb and analyzing the combined batches.

If tissue homogenization is permissible, and no important contamination is visualized in this step, it should be performed in order to get the best possible sample. For boron analysis, as reported in this paper, it is preferably not done except to make a coarse "mince" of the tissue. Glass tissue grinders are normally made only of Pyrex glass, which is a borosilicate glass, and must be avoided under all circumstances because they introduce gross contamination.[1] In most cases it will be found satisfactory to use the tissue in the form of pieces cut from the organ.

Present Procedure and Uses

Paper pulp is weighed out on an analytical balance. Part of it is transferred to the well of the pellet press, then a piece of tissue (preferably frozen) is sandwiched between this and the rest of the paper. Enough pressure is applied to form a pellet that holds together without crumbling. The complete pellet is weighed, and the amount of tissue incorporated is thus ascertained. The pellet is transferred to the combustion cup of the bomb and burned as previously described. The combustion process is all over in a matter of seconds or a fraction thereof. The bomb is cooled in an ice-water bath for some 10 or 15 minutes to condense all of the vapors, and the vent valve is cracked slightly to let the gases escape slowly. If volatile compounds are expected to be in the vapor phase, the gases can be bled through an appropriate scrubbing assembly in order to retain the desired components. This has not been found necessary in the case of boron analysis.

After disassembling the bomb, its contents are washed out carefully with distilled water and the washings are saved for boron analysis. If the concentration is too high, as detected by a preliminary test or estimated from experience (e.g. kind of animal exposure), the

† However, with proper precautions it is possible to employ a preliminary drying step if so desired and if losses by volatilization are not likely to occur. This would be particularly advantageous for control tissue because the drying step would make it possible to use a much larger sample (on the dry weight basis) in the Parr Oxygen Bomb. We employed drying at room temperature as well as at temperatures of up to about 300°C in some of our boron work and obtained reasonably good results, provided we made the tissue alkaline with caustic soda or sodium carbonate prior to drying. Even so, the results tended to be on the low side, and we would therefore not recommend this procedure as regular practice.

bomb contents are washed into a volumetric flask, diluted to volume and aliquots taken for analysis by the Carmine[5] or any other method. If the boron level is low, the bomb contents are washed into a boron-free beaker, 5 ml of approximately 0.6 *N* NaOH is added, the mixture is evaporated on the steam bath, and boron analyses are performed by any desired method. The Carmine method is the one preferred by us. The same amount of paper pulp as is used for the actual tissue analysis is burned in a separate test and the washings are put through the same process. This furnishes the chemical blank for the spectrophotometric analysis.

If all organic matter were burned completely, which should be the case after some practice and under normal circumstances, there is no need for a methyl borate distillation prior to boron analysis, as verified by extensive tests. Colored solutions are, in general, not usable for the Carmine reaction and must be subjected to methyl borate distillation first.

During the combustion of tissue in the Parr Oxygen Bomb, part of the protein nitrogen seems to be oxidized to nitric or nitrous acid. Originally it was thought that this bothersome impurity might be derived from the nitrogen of the air in the bomb. Efforts were, therefore, made to flush out the bomb with oxygen, after loading, in order to eliminate the air. While this might have resulted in a lowering of the nitrate normally encountered, it did not eliminate it and the conclusion seems justified that it is derived from the tissue protein.

In our original work several years ago[3] the amount of nitrate encountered was so large that methyl borate distillation was found to be imperative. The bomb washings also contained at that time sizeable amounts of nickel and other metals, which were attributed to the old and badly corroded bomb then used. When the presently reported work was started, it was soon found that only small amounts of nitrate are, in general, formed so that they are usually taken care of by the hydrochloric acid added during the Carmine step for the purpose of eliminating nitrate. However, if unusually large amounts of nitrate are encountered, it has been found that reduction with Devarda's metal will remove the nitrate satisfactorily and not introduce impurities inimical to boron analysis. Several small pieces of this metal are usually added to the bomb washings during the steam bath evaporation step because the alkaline conditions then prevailing are needed for proper reduction of the nitrate to ammonia. After reduction, the solutions are filtered and the filter paper is washed, before boron analysis is undertaken.

TABLE I

Comparison of (Average) Results Obtained on Tissues (Rabbit) with Parr Bomb and Alkaline Digestion Methods

Figures represent micrograms of boron per gram of wet tissue

Organ	56.3 mg/kg Dimethylamine-borane (I P)			75 mg/kg decaborane (I V)			100 mg/kg decaborane (oral)		
	Parr Bomb	Alkaline Digestion		Parr Bomb	Alkaline Digestion		Parr Bomb	Alkaline Digestion	
		1-step	2-step		1-step	2-step		1-step	2-step
Brain	8.3	8.6	9.2	45.5	—	47.1	29.2	—	36.6
Kidney	16.0	14.9	16.1	515.	538.	561.	78.2	71.7	67.7
Liver	11.6	11.7	12.6	493.	498.	507.	105.5	114.6	108.1
Lung	16.9	—	13.5	1206.	—	1245.	102.3	—	112.3
Muscle	9.5	—	12.9	13.6	—	10.5	32.2	30.3	36.7
Heart	—	—	—	2240.	—	1973.	47.5	—	43.8

TABLE II

Comparison of Results Obtained by the Parr Bomb with and without Methyl Borate Distillation and the Alkaline Digestion Methods

Figures represent micrograms of boron per gram of wet liver (rabbit). Exposure was 37.5 mg/kg of Dimethylamine-borane

Parr Bomb Method		Alkaline Digestion, 1-step procedure
without methyl borate distillation	with methyl borate distillation	
6.2		
7.5	6.9	5.8
7.1	6.9	6.0
6.5	7.0	7.4
6.1		
—	—	—
Ave. 6.7	Ave. 6.9	Ave. 6.4

The method has been used successfully for the destruction of such tissue as liver, kidney, brain, skeletal muscle and heart. Of these, liver and kidney offer the most difficulties on account of the physical properties of the tissue. Heart is at times also difficult to handle. These organs are apt to release blood and other fluids when pressure is exerted on them and care must be taken that it is not lost but rather absorbed by the paper pulp.

The combustion of blood and urine is in the developmental stage, and results obtained to date are most encouraging for the former. The latter presents a much tougher problem which, however, should not be insurmountable. It would seem well worth the effort because the stakes are high: the analysis of these biological materials for such elements as mercury, lead, thallium, fluorine and others, now difficult or cumbersome, should become simplified and possibly much more accurate.

The application of the Parr Oxygen Bomb to the destruction of vegetable matter in preparation for analysis suggests itself and seems, indeed, feasible. The following materials were burned in the bomb with entire satisfaction: cornmeal, rice (polished), oatmeal (slow cooking variety), soybean protein, laboratory dog chow, rabbit chow, orange peel and seeds, dry maple leaf and sawdust. No reason can be seen why the plant ash contained in the combustion cup could not be analyzed for any element by any desired method now in use for the analysis of plant ashes obtained by dry ashing in a crucible. Additionally, any volatile component would be found in the bomb washings, so that losses should be pretty well excluded.

The applicability of the method would seem to extend even beyond the analysis of tissue and other biological materials. The industrial hygienist especially is often called upon to abstract noxious vapors from air by means of activated carbon, as is the case for some of the boranes. Such loaded carbon could be burned in the Parr Oxygen Bomb and the desired element determined in the bomb washings and ash. Even materials like chlorinated hydrocarbons might be determinable in this manner.

Summary

The method of tissue destruction here described has given very satisfactory results when applied to boron analysis of animal tissue. Precision has, in general, been quite good, and the results obtained have compared favorably with those obtained by the alkaline digestion method[3], as may be seen from Tables I and II. The speed with which the analyses can be carried out permits a sufficient number of aliquots to be run so that dependable average values can be obtained. Much less laboratory equipment is needed for this method than for others, hoods are not required, corrosive acids are not employed, and the equipment occupies a minimum of bench space.

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Shoe-Fitting Fluoroscopes–their Outlawing in Pennsylvania*

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IN NOVEMBER 1956 The Advisory Health Board of the Commonwealth of Pennsylvania adopted *Regulation 433 "Radiation Protection"*. This regulation deals with all phases of ionizing radiation, and closely follows *Handbook 61* of the National Bureau of Standards. The first amendment, added in February 1957, outlawed shoe-fitting fluoroscopes. This paper is concerned with that particular phase of the regulation.

Shoe-fitting fluoroscopes are devices which are used primarily in shoe stores, theoretically for the fitting of shoes. Actually, they fall short of this purpose since the viewer can only see the bony parts of the foot, but is unable to distinguish the soft parts on the fluoroscopic screen. They are also used on occasion by chiropodists and in shoe manufacturing. In shoe factories they are used to look for misplaced nails.

Shortly after passage of *Regulation 433* a study was made of 80 shoe-fitting fluoroscopes selected at random. It revealed that customers whose feet were exposed received from 600 mr to several roentgens per viewing. It is, of course, impossible to control the number of viewings. People just love to see what's under their skin and there was nothing to stop them from going to one shoe store and then to another and having several exposures in a relatively short time. It was soon realized that shoe-fitting fluoroscopes could not be operated and still comply with the existing minimum permissible dosages of 150 mr for the feet, as prescribed in *Regulation 433*.

Regulation 433 limits the maximum permissible dose for occupationally exposed persons to 300 mr of total body radiation. The maximum permissible amount for the feet and ankles is five times this limit. However, the general population, as opposed to those occupationally exposed, may only receive one-tenth of this amount.

Has anybody ever been harmed by these machines? This question is always asked. There are definite cases. The first case comes from the files of Dr. Morris Kleinfeld, New York State Department of Labor:

"Mrs. E. worked as a shoe model demonstrating shoes under a fluoroscope from 1927–34. Usually the right foot was demonstrated but occasionally the left foot was used. Symptoms first appeared in 1934; skin irritation, itching, and formation of white blisters. In 1940, a partial amputation of the distal part of the right foot was performed. Since then she has had recurring rashes and recently has developed a growth which gave rise to intermittent bleeding."

A second case was described by Kopp in the British Medical Journal in 1957 (*2:* 1344).

"A woman, a shoe-fitting fluoroscope operator with radiation dermatitis, gave a history of having operated two fluoroscopes for ten years. The woman was in the habit of supporting her right foot on the platform of the fluoroscope in front of the opening where it was exposed to repeated radiation."

Most cases of radiation damage are slow to appear, and more cases can be expected within the next few years.

In order to determine how to proceed with action against these devices a conference was held with a representative of the Attorney General's office. It was learned that shoe-fitting fluoroscopes could have been prohibited under existing regulations, but it was decided to have a more specific regulation prohibiting them, and also to permit their continued use by licensed chiropodists and other qualified persons. In 1957 the Advisory Health Board of the Pennsylvania Department of Health passed the following amendment to *Regulation 433*.

"In order to protect the people of this Commonwealth from indiscriminate, unnecessary and potentially harmful exposure to radiation, the following regulation is promulgated:

"It shall be unlawful after February 1, 1957, for any person, partnership, association, or corporation to operate or maintain within this Commonwealth, any fitting devices or machines which use fluoroscopic, x-ray, or radiation principles for the purpose of selling footwear through commerical outlets."

Several states had regulated shoe-fitting fluoro-

* From a paper presented to the American Conference of Governmental Industrial Hygienists, Atlantic City, New Jersey, April 21, 1958.

scopes before Pennsylvania. Eight of them followed the model code of the American Conference of Governmental Industrial Hygienists published in 1950, but this code is much more concerned with exposure of the operator than with customer exposure. There are several states which have minor variations from the A.C.G.I.H. code. One state merely required posting of warning signs on shoe-fitting fluoroscopes. Other states required registration only. Twenty-two states had no legislation.

Washington, D. C., the first to curb shoe-fitting fluoroscopes, outlawed them in a subtle way. The regulation reads as follows: "Only a licensed physician can operate the machines". Not many physicians sell shoes these days.

The New York State Regulation 19 reads as follows:

"No person shall apply radiation to a human being unless such person is licensed or otherwise authorized to practice medicine, dentistry, podiatry, or osteopathy under the provisions of the education law of the State of New York."

Pennsylvania was the first state to outlaw shoe-fitting fluoroscopes. Vermont, Texas, New York, South Dakota, and Montana soon did likewise and, since the writing of the original draft of this paper, Massachusetts, Mississippi, Virginia, and Hawaii have also outlawed shoe-fitting fluoroscopes. Ohio has passed enabling legislation to outlaw them. Six states which presently have no regulations, and five states which have, are at this point considering outlawing the shoe-fitting fluoroscopes.

These statistics are based on a survey which was undertaken in December 1957, and to which all 48 states replied. There were still about 6,000 shoe-fitting fluoroscopes in 36 states at that date. In some states the figures were based on estimates, in others on actual counts or registrations. Seven states had neither figures nor estimates of the number of machines.

Since Pennsylvania was the first state to outlaw the machines there was considerable interest in how the regulation would be received—especially since some attorneys, in other states, had gone on record stating that such outlawing would be unconstitutional. It was thought that there was discrimination involved. The Pennsylvania regulation clearly states the maximum allowable dose of radiation for human beings—and the only exception for human application of radiation is granted to the healing professions. If an exception were granted to shoe stores, other requests might be as justifiable.

A few letters were the only complaints received. Just a few weeks before the amendment was passed, the Philadelphia Shoe Retailers Association went on record that these devices serve no useful purpose, and that a good shoe salesman can fit shoes as well, if not better, without the fluoroscope. On the whole, most shoe store owners seemed pleased to get rid of the machines. As long as competitors did not have one there was no need for them.

In the preparation of the new amendment for the outlawing of shoe-fitting fluoroscopes, one item was overlooked. Others are advised to profit from our experience. A check on the disposal of shoe-fitting fluoroscopes was forgotten. It is now known that a large number of Pennsylvania's 800 shoe-fitting fluoroscopes went into neighboring states. Two have turned up in high school physics departments—and it would be interesting to know where others have found homes.

Just recently an interesting advertisement from a Baltimore newspaper was received. It read:

"For Sale: Shoe-fitting fluoroscope. Any offer accepted."

Summary

Shoe-fitting fluoroscopes are devices which cause a relatively high radiation exposure to the feet of the unsuspecting customer. They were most often operated by untrained personnel and it was felt that they constituted a source of unnecessary radiation exposure which could not be justified and could not operate in compliance with the maximum permissible doses as outlined in *Pennsylvania Regulation 433 "Radiation Protection."* For that reason they were outlawed in Pennsylvania in February 1957.

Use of a Gamma Ray Spectrometer for Investigation of Plutonium Contaminated Wounds*

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Introduction

A GAMMA ray spectrometer has been used on several occasions to estimate the amount of plutonium in wounds by measuring the L x-rays from Pu^{239}. Good agreement was obtained between in-vivo measurements before and after excision and alpha particle analysis of the excised tissue. With the equipment used the estimated lower limit of sensitivity is 0.1 μg of Pu^{239}. Refinements in shielding, electronics, crystal size and crystal can thickness could be expected to increase this sensitivity.

Description of Detector

The detector consisted of an RCA 6342 photomultiplier tube, a 1.5-inch by 1-inch deep NaI(T1) Harshaw canned crystal and a magnetic shield assembly all mounted in a lead shield and collimator. (See Figure 1.) High voltage for the detector was furnished by a John Fluke Mfg. Co. Model 402 supply set at 1000 volts.

The output of the RCA 6342 was connected to a Beva Lab Model 154 linear amplifier. This in turn was connected to a LASL Model 10A analyzer. The location of the x-ray peak was determined by scanning a Pu^{239} source with the instrument set for a one-half volt window width which was equivalent to 0.62 kev. Calculations made on the resulting curve gave the peak location at 17 kev with a peak width at half-height of 7.4 kev. Dividing half-height peak width by peak energy yielded a resolution of 44%.

The window was then opened to a width of 5 volts and centered on the 17 kev peak. Counts within the range 13.9 kev to 20.1 kev were recorded on a decade scaler. A thin plutonium standard of 0.45 μg yielded about 70 net gamma counts per minute. Background was in the region of 20 counts per minute. No corrections were made for absorption nor for varying geometry with depth and degree of dispersion of the material in the wounds. The spectrometer estimates are presented as surface equivalents.

Measuring Techniques

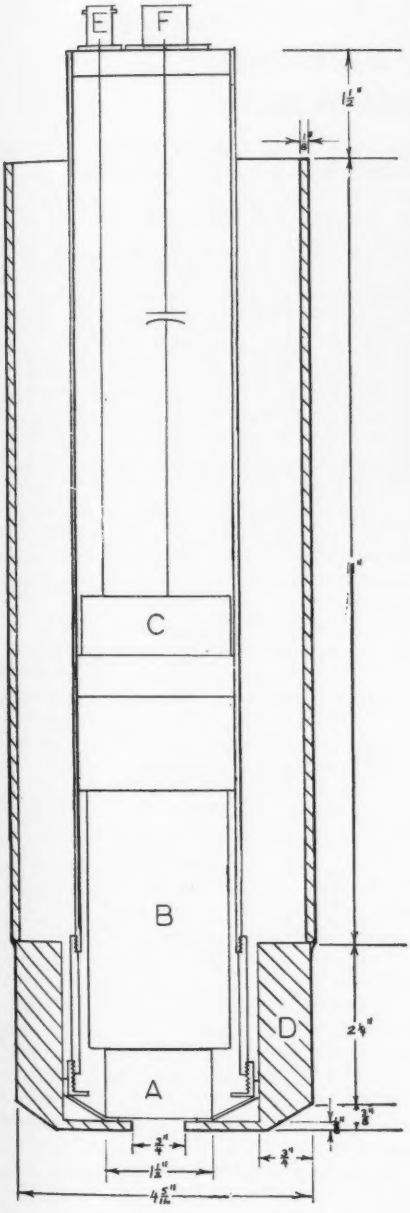
The detector shield was designed such that the detector could be easily removed. For wounds which occur at locations of the body which present difficulty in aligning the wound with the detector shield aperture, the detector is removed and the wound is easily "bore sighted" into the aperture. The detector is then returned to the shield and a measurement is taken.

In some cases it has been desirable to attempt to pin-point the contamination to a smaller area. This has been done by stopping down the ¾-inch aperture by using several layers of lead tape. The aperture in the lead tape can be cut to any predetermined size. Figure 2 shows the detector stopped down to a ¼-inch square opening. The lead tape used represents 0.024 inches of lead. Four layers of lead tape is sufficient to reduce the x-ray count of a 220-μg polutonium source down to background.

A convenient method of pinpointing activity is to stop the aperture down to a square or rectangular opening. A grid area can then be drawn with an eyebrow pencil in the area of interest around the wound such that the small areas of the grid are the same dimension as the aperture. Each small area is numbered for identification and easy "bore sighting."

The surface equivalent gamma spectrometer measurements and alpha analysis for five examples are shown in Table I. The gamma spectrometer has become a routine instrument at our plant for monitoring wounds originating in plutonium areas. Although the instrument is at best semi-quantitative, it definitely has reduced the uncertainty that previously existed in handling such wounds.

* U. S. Atomic Energy Commission Contract AT(29-1)-1106.



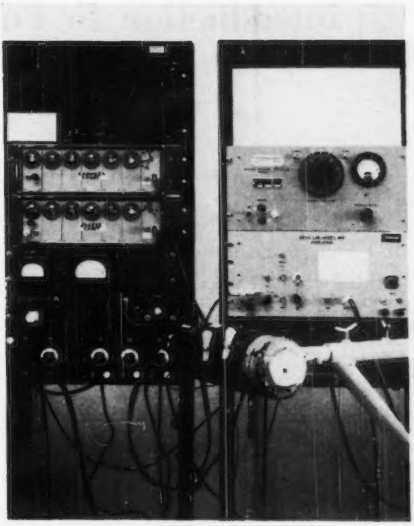


FIGURE 2. Detector Shield

TABLE I

Analytical Data

Gamma Spectrometer Surface Equivalent	Alpha Analysis
2.56 μg	2.58
1.86	2.30
0.47	0.26
0.42	0.56
0.42	0.34

FIGURE 1. Cross Section of Detector Head and Shield.

A. NaI (T1) Crystal
B. RCA 6342 Photomultiplier
C. Diheptal Socket
D. Lead Shield
E. H.V. Input (+1000 v)
F. Signal Output

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Introduction to Fourth Noise Conference of Associated Industries of New York State

JOSEPH R. SHAW

President of Associated Industries of New York State, Inc.

I BID YOU welcome to our Fourth Industrial Noise Conference.

I well remember exactly five years ago when our Workmen's Compensation Committee was considering the very serious problem of occupational loss of hearing. Someone on the committee suggested that we hold a Noise Conference. Others on the committee encouraged that suggestion and stated that things could be accomplished in noise control and much more progress could be made.

When we explored the idea a little bit, we were met with people who sort of scoffed and were gently amused, and we more or less took it for granted that nothing could be done about certain types of noisy operations. It was apparently the type of thinking with which too many people in industry have been imbued for many years.

And on locking a little further into the problem, we found that in certain types of industries nothing had been attempted. For instance, with respect to the design of certain fundamental machinery, no change had been made for fifty years.

Well, we went ahead with that first Noise Control Conference. It was held in Schenectady, with the splendid cooperation of the General Electric Company. We held it at the Knowles Laboratory, in their auditorium, in Lakewood. It was a modest beginning.

Because it was successful, we were encouraged to hold a second Noise Conference in Rochester the following year. In 1955 we held our Third Noise Conference in the City of Buffalo.

The following year our Committee on the Noise Conference felt that there were not sufficient developments which had occurred in the interim to hold another Noise Conference and we held off a year.

And so you see, ladies and gentlemen, the men who planned this conference, the experts from industry, the best brains in the country in the field of engineering and other related fields bearing on noise control did not want to hold a Noise Conference merely for the sake of holding a conference. They decided to hold this conference because they feel there are sufficient new developments in the field of noise control to be of value to you in industry.

And so the interest in this whole area has grown. It has grown very significantly. And the breadth of that interest is best indicated by the representation here today. Among you gentlemen we have representatives from industry, from insurance and from other fields. We have industrial hygienists, doctors from the field of industrial medicine, engineers, lawyers, top executives, safety directors, personnel directors, industrial relations directors and many others. To me that is the best indication of the breadth of interest in this subject and indeed a better indication than anything else.

I want to pay particluar tribute to the men who have been so closely identified with our Noise Conferences over these few years. We have been fortunate in being able to draw upon the best brains from American industry. This committee is made up of men from all fields of industrial hygiene, engineering, medicine and law, and they have put together a program which is timely.

Industry is deserving of praise for the work that they have done in this field of noise control. I think you will agree that all too often today industry is unfairly attacked. They are smeared, sneered at and criticized. It isn't often that industry gets a little praise for something they have done not in just a selfish interest but in the interest of the employee and the interest of our industrial economy. And it is my feeling that industry has not received the praise which it deserves. I think they are entitled to a lot of credit because progress in the field of noise control is not only directly beneficial to industry itself, it is good for the employees, it promotes efficiency, and it helps our industrial economy as a whole.

A great incentive for taking active steps to further progress in this field was provided with the passage by the New York State Legislature, just a little over a month ago, of a very fundamental piece of legislation on occupational loss of hearing.

Noise and its Effect on Hearing

JAMES H. STERNER, M.D.

Eastman Kodak Company, Rochester, New York

IN THE TEN-YEAR interval since the decision by the New York Court of Appeals sustaining the award for occupational loss of hearing—the oft-quoted Slawinski case—so much research and investigation has been carried out, so many meetings and symposia conducted, and so many papers, collected proceedings, journals and monographs published on the subject of industrial noise and its effect on hearing that even those individuals devoting full time to the subject have had difficulty in keeping oriented. Substantial progress has been made in the evaluation of the effect of noise on hearing, and much has been accomplished in the elimination and control of hazardous noise from industrial and commercial sources. Admittedly, there is much more to be done than the mere dotting of "i's" and crossing of "t's", but we feel much more secure that the research, interest, and effort thus far generated will be sustained and extended to achieve a reasonable and acceptable solution. The wider application of control procedures must be further stimulated, and any inertia related to a wishful thinking that the problem is less real than when projected ten years ago is completely unjustified.

The subject, *Noise and Its Effect on Hearing*, has been summarized in an effective and authoritative manner in several recent publications. Particularly to be recommended is the *Guide for Conservation of Hearing in Noise*, issued by the Subcommittee on Noise in Industry, and approved by the American Academy of Ophthalmology and Otolaryngology, the Council on Industrial Health of the American Medical Association, and other professional organizations with competence in this field. It seems to me, the justification for this discussion lies in emphasizing and interpreting to you the areas where significant agreement has been achieved, and those elements which must be further explored and developed to help us in the solution of the problem.

To help in our perspective, it seems appropriate to note a meeting held here in New York in February 1950. At that Tenth Annual Meeting of the Congress on Industrial Health of the American Medical Association, the then infant Subcommittee on Noise in Industry of the American Academy of Ophthalmology and Otolaryngology (hereinafter called A.A.O.O.) met with an even more infantile Committee on Physical Agents of the Council on Industrial Health, and issued what I believe is the first joint report on "Noise in Industry" which carried the tentative but official approval of these two large professional groups. This conference report was published in the *A.M.A. Archives of Industrial Hygiene and Occupational Medicine* in March 1951, after much scrutiny of substance and phrasing by the parent organizations. The major credit for the vision and soundness of the conclusions and recommendations must go to Dr. Stacy Guild (with whom I had the privilege of serving as Co-Chairman) and to his associates on the Subcommittee. This report is noted since it will serve as a reflective framework for viewing what has developed in these succeeding eight years.

The initial conclusion, "Noise Can and Does Cause Deafness", was seriously doubted, or at least regarded as insignificant by a considerable number of people who already were involved in the problem—or by the problem. A much greater number were totally unaware that the problem existed, or were indifferent to it. With the further developments in the Workmen's Compensation activity, and a great deal of educational effort—of which these conferences sponsored by Associated Industries of New York State are an excellent and effective example—a constructive change in the recognition of the problem has occurred. There are certainly few, if any, interested observers who would doubt that industrial "noise at certain high levels of intensity presently existing in industry" can cause loss of hearing. This recognition was essential if interest, effort, and money were to be mobilized for an attack on the problem.

Considerable progress has been made with respect to the identification of intensity, frequency, and duration of noise which may be hazardous. In a study presented at the University of Michigan Symposium on Noise in 1952, the scatter of judgments from a group of individuals with some experience with the noise problem was so wide and so variable that the majority of participants agreed the data thus far developed were adequate only as a rough guide for beginning control operations. Many people are impatient that, with a considerable amount of additional research, we still cannot establish standards—or better, criteria—for noise control with the accuracy and reliability

needed for medico-legal purposes. We must agree with the present conclusion reported in the "Guide" referred to above: "At the present time our knowledge of the relations of noise exposure to hearing loss is much too limited for us to propose safe amounts of noise exposure.... If the sound energy of noise is distributed more or less evenly throughout the eight octave bands, and if a person is to be exposed to this noise regularly for many hours a day, five days a week for many years, then: if the noise level in either the 300–600 cycle band or the 600–1200 cycle band is 85 db, the initiation of noise exposure control and tests of hearing is advisable. The more the octave band levels exceed 85 db, the more urgent is the need for hearing conservation."

It must be understood that over-all noise levels of 95 or 100 db can occur without either of these critical octave band values equalling or exceeding the 85 db level.

Other studies have indicated that for equal energy values, steady noise is more injurious than interrupted noise exposure. The development of instruments which permit the accurate measurement of noise over very long periods has revealed the limitations of our standard sound level meters in assessing the character of many types of industrial noise; much wider fluctuations of intensity are found than would be estimated from spot or repeated samplings.

The recommendation of the 1950 conference that "extensive, well-controlled field studies must be made to provide essential, reliable information on the effect of noise on hearing, under actual industrial conditions" has been amply confirmed. As these studies have progressed, their importance has become emphasized. Much of the earlier data has been shown to be inaccurate, incomplete or inadequately controlled to provide reliable correllations of physical and medical findings. The recognition that the studies must extend over a wide variety of patterns of industrial noise to assess the functions of intensity, frequency, and duration necessarily delays the development of criteria. The finding of significant exposure differences in groups previously considered to have a common exposure has markedly limited the size of the useful sample. It is to be expected that in a study of such a complex subject these kinds of experiences—and difficulties—would be encountered. None of them are insurmountable, and with each improvement in our understanding and methods, we have increased the reliability of our final solution. Studies are continuing, with a clearer definition and purpose, and as these accumulate in sufficient variety and quantity, they will be translated into the criteria needed to control the industrial hazard and to guide in a more reliable and objective manner the adjudication of medico-legal problems. It is hoped that the professional societies with recognized competence in the various fields contributing to the solution will accept a cooperative responsibility to establish such criteria, equating the factor of need and validity of data in timing their action.

There is renewed hope that progress can be made in the methods for evaluating disability from hearing loss. There is urgent need for the establishment of a method which has the approval and acceptance and the weight of authority of the national professional societies. An earlier committee, with representatives from the Council on Physical Medicine of the American Medical Association and the Committee on the Conservation of Hearing of the A.A.O.O. made an important contribution with the publication of *Principles for Evaluating Hearing Loss*. The need for a better method is amply demonstrated by the variety of procedures established by the various states. It is reasonable to assume that the representatives from national professional societies will develop more objective and more widely acceptable standards. The reluctance to develop criteria based on incomplete information must be balanced against the hard fact that an overriding need is forcing the emergence of a variety of standards with inequalities and inconsistencies.

An important quality which distinguishes the present status of our attitudes and knowledge concerning the relation between noise and hearing loss cannot be gauged from any individual paper or monograph. It consists of a much greater clarity with which we view our objectives, of a quiet but increasing confidence that ways have been and will be found to control our noise hazards, of a better organized and more purposive attack on all aspects of a problem which once seemed only elusive and confusing. We should take some satisfaction that we have progressed thus far along the path, but then must return to the the cold reality that we have a much longer distance still to go.

New York State Loss of Hearing Legislation

DONALD L. HAYES

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MY REMARKS are intended merely to give you some of the background leading up to the enactment of the new amendment to the Workmen's Compensation Law* dealing with cases of occupational loss of hearing and the reasons for some of the provisions contained in this amendment. I will not at this time attempt to interpret any of these provisions.

Declaration of Purpose

The problem of loss of hearing was created due to a decision of the Court of Appeals in 1948 in the case of *Slawinski vs. J. H. Williams Co.*, 298 N.Y. 546. Up to the time of this decision it had always been presumed that loss of hearing was compensable only if there was disability which involved a wage loss and then only as to the extent and period of the disability. However, the *Slawinski* case changed all this and added a new concept that permanent partial disabilities due to hearing loss were compensable under the permanent partial schedules, the same as permanent partial disability due to amputation or loss of use of members. This, of course, opened the door to many problems and to the fear that industry would be swamped with claims, especially in the noisy industries. Under this new concept, the employee would not have to lose time or show any wage loss.

During the first two or three years after this decision there was not too much activity on this subject. However, not long after this a case arose in Wisconsin, namely the case of *Green Bay Drop Forge Co. et al v. Industrial Commission and Albert Wojcik, 265 Wisc. 38.* To some extent the Wisconsin Law was always assumed to be similar to that of New York, in that payment would only be made in the event of a wage loss. However, the Wisconsin case, which also upheld the principle of compensation on a schedule basis where there was no wage loss, got national publicity because of the fact that there were a number of claims filed against employers in Wisconsin. In other words, attention was focused on the problem and it became very acute in the State of New York. Obviously any corrective measures lay only in securing legislative amendments to either clarify the intent of the law or to offset the Slawinski decision.

Most of all the fear of an avalanche of claims was the most impelling motive, and therein begins the history of our efforts to obtain some measure of relief, or at least to allay the fear stemming from this new and unknown liability. The first steps were taken by the Workmen's Compensation Board through Miss Mary Donlon who appointed a Committee of expert consultants to study the problem. Among other things, one of the most important recommendations they made was that as long as employees were exposed to noise, the question of permaneney could not be determined until they were removed from the noisy exposure for a period of at least six months. Miss Donlon and the Workmen's Compensation Board thereupon adopted a rule that schedule awards in loss of hearing cases would not be made until the six-month rule requirement had been met.

We in industry were appreciative of the Board's action, as it would provide some measure of relief even though it was based upon very shaky grounds. Those of us who were vitally interested were always fearful that a new chairman or a new Board might reject the rule. This fear proved to be unfounded, as our present Chairman, Miss Angela Parisi, and the Board, realizing the seriousness of the problem, continued the rule in effect. However, there was another situation that worried us and that was the possibility that the rule might not stand a "court test". In other words it seemed to us that the reasonable and logical solution would be legislative relief.

Because so many things happened, I can only give you an outline of the efforts that took place to accomplish our objective. Originally we felt that the solution would be to restore the wage loss concept to the Act. Without going into details, after several years of effort it was apparent that this could not be accomplished. The Ostrander Committee, which is a bi-partisan committee of the Legislature, took up the problem and in 1955 at a meeting at Whiteface it was

*Article 3-A, Senate Bill, Introductory Number 3696, Print Number 4544, Senate Bill, Introductory Number 3763, Print Number 4568, signed by Governor Harriman April 23, 1958, effective July 1, 1958.

suggested by labor that a committee be formed representing both labor and industry to attempt to come up with a solution. As a result of that meeting, a sub-committee of the Ostrander Committee was appointed. The members of the committee were: Mr. Harold Hanover, representing the AFL; Mr. Harry Tiernan and Miss Marion Polakov, representing the CIO, Eighth District Steel Workers; Mr. Anthony Giglia, representing the International Association of Machinists; and Mr. Thomas Nelson of the UAW. Industry was represented by Mr. Joseph R. Shaw, President of Associated Industries; Mr. Miles Robertson, President of Oneida Limited, Oneida, New York; Mr. Donald L. Hayes, President of Laverack & Haines, Inc.; and Mr. Noel S. Symons, a member of the firm of Vaughan, Brown, Kelly, Turner & Symons, and Legal Consultant on Industrial Noise to Associated Industries, and who acted as counsel to the committee.

Without going into all the details, I, as a representative of the committee and of the subcommittee which was comprised of Mr. Tiernan, Miss Polakov, Mr. Nelson, and Mr. Symons, publicly want to thank the labor members for their understanding and their willingness to help solve this very difficult problem. We are indebted to them for many of the suggestions which I will describe later. As a result of this sub-committee's recommendation, a bill was drawn which did not meet with the approval of any of the sub-committee who drafted it. The reason for this was that we were, as a subcommittee, not empowered to approve it. Our only obligation was to recommend. It is now history, but there were many difficulties during the legislative session and unfortunately the subcommittee did not have the time available to come up with a perfect piece of draftsmanship.

My purpose today is not to attempt to interpret any of the sections of Article 3-a entitled *Occupational Loss of Hearing*. The purpose is to give you some of the reasons and intent behind each of the sections. I have already given you the background that led up to the present, and will therefore take up each section in order.

Waiting Period

The waiting period was agreed to by all, both labor and industry. Now I want to say that as far as intent is concerned, the basic reasoning for the six-month waiting period is not, as many think, based on medical theory. After much discussion we all agreed that the six-months postulate was a socio-economic necessity. In other words, it was agreed that the six-months postulate did not deny the payment of claims but simply postponed them until such time as the claimant could qualify for awards, the theory being that it would stagger the claims and would prevent the thing that we were fearful of, a sudden avalanche of claims.

In the discussions we had it was very obvious to us that our present rule was not actually helping, but in some respects injuring the efforts of the engineers and the doctors to do a good job on noise control.

As an illustration, in the report of the expert consultants it was presumed that under certain conditions noise levels of 90 db and over would be considered harmful. Under the rule as it exists now, but which we changed as of July 1st, the rule provided that the claimant was eligible for a claim six months after his removal from injurious exposure. Now, here is where the catch comes. You can have a room, and I have used this illustration many times, with 100 employees in it where your db level may be 95. Through engineering means, and improvement in your operations, you drop that to 85 db, which is a substantial drop in the noise level. Now, 85 db theoretically is not harmful. The men have not changed their jobs, they are still working in the same room. Six months later each man in that room who may have some loss of hearing which could be attributed to noise is eligible for a claim. Obviously, no one with any common sense is going to attempt to reduce the noise under those circumstances because to do so immediately opens the door for many, many claims. Labor recognized this. We recognized it. And as a result we said that if the six-month postulate must be from the last day of injurious exposure then we are going to defeat the purposes which we all should be looking for and that is to improve working conditions for the employees.

Coupled with the six-months postulate it was absolutely essential to fix a date of disablement. Previously the date of disablement for those of us who had to actually handle claims was a very elusive thing. It might be set as the date of an audiometric examination, as the last day of employment, or it might be set as the last day of injurious exposure. In other words, it was not safe to attempt to predict what the date of disablement would be in any given case. The labor members felt, as we did, that we ought to have a definite date of disablement, and if any of you have read the bill, you will find that the interpretation of the six-months waiting period is: six months after separation from work for the last employer in whose employ the employee was at any time exposed to harm-

ful noises and the last day of such period of separation from work would be the date of disablement. I believe it is clear, and there should be no dispute as to what is meant.

Right to Compensation

The right to compensation provides a limitation that no employee is to receive in the aggregate a greater amount than the amount provided for total loss of hearing under Subdivision Three of Section 15 of the Workmen's Compensation Law. In the same section we also provided that compensation is not to be deducted from benefits to any employee under any welfare plan, pension plan, agreement, or trust to which such employee is a party or of which he is a beneficiary.

We have been asked many times why this was included. As far as intent is concerned, it is well to remember that our paramount objective was the six-months waiting period. It is also well to remember that we established that the date of disablement was six months after the last day of work. Labor took the position, and we believe rightly so, that, by agreeing to the six-months postulate, unquestionably many of these employees would continue to work until they retire, and that it was only by operation of the six-months waiting period that they were not entitled to benefits prior to retirement. Certain of the unions raised very serious objections that they would not go along with the six-month period if awards were to be deducted from pension benefits. This particular section may come in conflict with certain sections of the New York State Retirement Law; however, we did the best we could with it.

Posthumous Schedule Awards

This question came up as there had been some cases where claims were made after death. Under accident injury cases we were all well acquainted with the fact that the law provides that a schedule loss, provided there is proof of the loss, can be made after death. All we did was simply to clarify the fact that posthumous schedule awards could be made for loss of hearing provided there was supporting evidence of such loss.

Liability of Employer

This was the most difficult problem that we had. From an administrative standpoint it would have been simpler to follow the procedure set up for the occupational disease of silicosis wherein the last employer, if the employee became disabled, was liable for all of the compensation. However, we on industry's side had considerable difficulty with this particular section. Occupational deafness is not a true occupational deafness in most cases. It is a mixed type of deafness and there were many employers who rightfully felt that upon the employment of an individual who had substantial loss of hearing that they should not be required to pay for the entire loss. However, there were many problems to consider. While we do have an apportionment provision under the law for occupational diseases at the present time, it is unworkable insofar as loss of hearing is concerned.

Again we express our appreciation to the labor members of the Subcommittee, as they recognized the problem. While they were not willing to give up any of their rights as to the final award, they did agree that if the last employer was made liable and a suitable apportionment provision could be made, they would go along.

The committee has studied the Wisconsin Act in respect to apportionment, and there were some things we did not like about it which we tried to avoid in our situation. In Wisconsin, apportionment is provided, but one of the difficulties is that the claim is timely, when filed against the last employer, as against all prior employers where he may have been exposed with no provisions for notifying prior employers that they might be called upon at some future time to bear part of the loss.

Briefly, what we attempted to do, and we think we have succeeded, is to give the last employer, if he desires, the right to do preplacement examinations, and the right to claim against a prior employer if the prior employer is responsible for any portion of the loss. We accomplished this by requiring the last employer to give the prior employer 90 days written notice from the date of the examination, and we further provided that the prior employer would have the right to make an examination and to prepare to defend himself should he be called upon to do so. We realize that it is going to be difficult to set up the machinery to carry out the intent of this section and we have assured the Chairman of the Workmen's Compensation Board that we will meet with her and those she designates, to administratively work out the provisions of this section, but plainly the intent of the law is to put prior employers on notice of a pending claim so that five, ten or fifteen years later they would not be faced with a claim of which they were unaware, which we think, can happen under the Wisconsin Statute. In any event, I

want to make it clear that this apportionment provision was inserted in the law for the benefit of any employer wishing to take advantage of it.

Minimum Exposure Required

Both labor and ourselves agreed that in order to avoid paying for "floaters" coming in from out of State for short periods who might be eligible for claims, that we would require that they be exposed for a period of at least 90 days in this State. This more or less follows the same procedure that was used in the silicosis legislation, and the only intent is to protect New York employers against the "floaters".

Determination of Criteria and Standards

Without going into detail, the members of the committee, none of whom were doctors or engineers, felt that it would be unsafe for us to attempt to write into any statute a formula for the measurement of hearing loss or standards regarding harmful exposures. Being aware of the fact that Miss Parisi already had a board of expert consultants, we felt that this area logically was one that could be best handled by the Workmen's Compensation Board. Those who are active in this matter certainly will offer all the aid and assistance that they can in connection with the adoption of rules and regulations consistent with this section.

Closing

In closing, I want to repeat that there probably will be defects discovered which may require legislative changes or interpretations by the Board. The legislation was set up in the form of an article, rather than an attempt to amend many different sections of the law, which we felt would be a very difficult matter because of the possibility of error or omitting to amend a section of the law which may later be found to be in confiict with the sections amended. As to precise answers to some of these problems, it is now up to the doctors and the engineers. We, as a committee, feel however that much work can be done in the elimination of noise and in the improvement of medical science with reference to loss of hearing, and this is to be greatly desired. As long as we have the ground rules now laid down, Industry has a pretty good idea of just what they can do toward the elimination of the hazard.

Hearing Conservation in New York State

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THE SUBJECT to be considered is the status of hearing conservation programs in New York State and their value to the employer and employee. The term *hearing conservation* is broad. Many plants in New York are actively engaged in the reduction of noise produced by equipment and operations, and are providing personal ear protective devices. These are important phases of industrial hearing conservation. On the other hand, very few employers in New York have a program of audiometric examination, and such programs to date are pretty well confined to very large plants. Due to time limitations I will confine my comments to audiometric programs here in our state.

I might explain briefly the audiometric program in operation in what can be considered a smaller New York State plant employing under 500 persons. This plant, through their insurance carrier, obtained a recommended audiometric examination procedure from the Academy of Ophthalmology and Otolaryngology. Management then called in a local otologist for consultation concerning the type of audiometer to be used. The insurance carrier tested various locations for noise levels by octave bands. A location was selected and an audiometric booth, approved by the consulting otologist, was purchased. The plant nurse was then sent to one of the outstanding otologists in New York for training in the operation of the audiometer. At this point the employer had the equipment, the trained technician and the services of an otologist.

The next step was to again call in the consulting otologist and obtain his approval of the entire set-up, including the manner in which the audiometric tests were given by the technician. The otologist also prepared standing orders under which the technician would operate

in the future. When certain audiometric findings were made the otologist left orders that such persons were to be referred to him for further examination and diagnosis. In other cases where the results of the tests were within certain limits specified by the otologist, no action beyond the making of the test was recommended.

This procedure has been in operation at this plant for approximately four years. Pre-employment tests have been continued and the testing program has been expanded to include periodic re-testing of those persons exposed to noise levels in which the otologist feels re-examination is desirable. The results of the program to date have been excellent. Ear protection has been provided where long exposures indicate that the noise levels are having an adverse effect on hearing. In two instances, persons who showed a very rapid reaction to high noise levels have met with management and the otologist and have accepted employment in lower noise level departments. There has been no agitation, no labor-management problems, no hearing loss claims filed and both management and the employees feel that the program is of benefit to both parties. It may be of interest to you to know that the cost of the equipment required was $1,541.00—roughly 23% of the cost of a single award for total hearing loss, at a weekly benefit of $45.00.

There are two basic reasons why audiometric examinations are not more widely accepted by industry. First the facilities, equipment, special training and medical supervision are both costly and confusing to the smaller plant. The answers to controlling costs and alleviating the confusion were well presented in other papers. The second reason for resistance to audiometric examinations has been the fear of stimulating a rash of hearing loss claims. There have been no reported increases in such claims by any company in New York as a result of a hearing conservation program, and plants which have conducted audiometric tests are convinced that this fear is overemphasized.

This is not a technical paper so perhaps I will be excused for departing from the normal procedure to present my subject by answering hypothetical questions which would logically be asked if we were sitting in a bull session discussing this topic. I'd assume the questions would develop something like this:

1. What is the purpose of the pre-placement audiometric examination?

Such examinations are given to determine the hearing acuity of an individual before he or she enters the plant's work environment. The results also distinguish those persons who should be further examined by an otologist.

2. As an employer, can I deduct the hearing loss found before employment from the hearing loss determined if a claim is filed after the individual is on my payroll?

An actual deduction cannot be made by the employer. However, there are apportionment provisions in at least two states which, when proper procedure is followed, may relieve the last employer of hearing loss suffered prior to his employment.

In Wisconsin the law provides for apportionment among prior employers of the proven pre-existing hearing loss. In New York there is now a new law, explained earlier by Mr. Hays, which provides a somewhat similar apportionment provision. It takes time to find out exactly how any new law will be interpreted but at least there is now an apportionment provision, specifically applicable to occupational hearing loss, in New York State.

3. Why should I, as a New York State employer, embark on a program of pre-placement audiometric testing?

There are three sound reasons for such a program. First, the placement of a person with defective hearing can be an important factor in your Workmen's Compensation costs. Such a person, when his handicap is known, can be placed in an area where his inability to hear does not increase the possibility of an accidental injury. Furthermore, with proper medical advice such an individual can be placed in an environment where the exposure will not cause further occupational loss. In themselves these reasons may not be confined to New York State, but we all realize that the cost of Workmen's Compensation is such that we can ill afford, from the standpoint of economics alone, to ignore any procedure which may prevent an accident or occupational disease.

The second reason was highlighted by a recent decision by the Supreme Court, Appellate Division, Third Department, which indicates that knowledge of an individual's hearing loss can entitle the employer to the benefits of the Second Injury Law. Briefly, this law entitles the employer to reimbursement by the fund for any benefits in excess of 104 weeks where the employer can prove he was aware, before the event of the subsequent injury or disease, that the individual concerned had a permanent physical handicap. If you are not familiar with this law, it would be well to study it thoroughly.

The third reason concerns the new occupational loss of hearing law. Although we can ex-

pect, as seems to be the case in many new laws, interpretations which may differ from the true legislative intent, we can be certain of one thing. Without pre-employment audiometric examination, apportionment of pre-existing occupational hearing loss will be impossible.

We can briefly summarize the value of pre-employment audiometric testing in New York State as follows:

Intelligent use of the results—

1. Can prevent *accidental* injuries by proper placement of the individual who has a substantial hearing loss;

2. Can conserve hearing by proper placement of individuals who already have a nerve type loss;

3. Can be used as proof to qualify for the benefits of the Second Injury Law;

4. May entitle the employer to relief for occupational hearing loss that pre-existed his employment.

The second phase of audiometric examination has been presented by Dr. Mieter and Dr. Maas. This is the in-service program where employees already on the payroll are rechecked at scheduled intervals. The following questions would be typical:

1. Briefly, what is the purpose of such a program?

The in-service audiometric testing program is designed to pinpoint minor changes in hearing so that preventive action can be taken before permanent and major damage occurs. This is an extremely important phase of the hearing conservation program.

3. Does the discovery of defective hearing among individuals already on our payroll also present the possibility of invoking the benefits available under the Second Injury Law?

It certainly does. The Second Injury Law pertains not only to handicaps which exist at the time of employment, but also to handicaps which develop while the employee is on your payroll.

Noise and its consequences are apparently here to stay. We who are in industry, or those of us who serve industry, must work as diligently to conserve hearing as we have worked in the past to prevent accidental injuries. Science has given us much of the equipment to do the job and it seems that it is up to us to use it intelligently.

In closing, I hope you will tolerate a little reminiscing. Technological progress has certainly complicated the life of a safety engineer. We used to work with men, machines, and methods —now we are confronted by protons, neutrons, electrons, radiation, isotopes, decibels, absorption coefficients, octave bands, audiometers, frequency analyzers, attenuations and medical terms which defy pronunciation. There are other persons, some of them here today, who may disagree with me when I say that it is not necessary for plant management to understand the technical aspects of the situation in order to do a good job of hearing conservation. The longer the problem is obscured by the jargon of scientific and technical terms, the longer it will be before industry as a whole will feel it is in a position to work towards a solution. I certainly have no quarrel with science and medicine. I do feel, however, that we have been prone to over-complicate the situation and that real progress will be made when industry realizes that effective hearing conservation programs can be established without first employing a full-time acoustical physicist, otologist and audiologist, and without a complete understanding of all the technical terms involved. When we recover from the icy shock of being confronted by a very technical and serious problem, we will soon find that there is a practical solution, no more complicated than the physical examinations, the machine guarding programs and the personal protective equipment which have long been a part of the industrial safety programs.

Compared to the magnitude of the problem ahead of us, progress has been slight and much remains to be done in the field of hearing conservation in industry. New York State industry is to be commended for meetings such as this where an exchange of practical ideas contributes to the growth of the conservation program. Our industry is making progress toward the solution of a very knotty problem. We can expect new developments and legislative revisions in the future. In the meantime, we must use the equipment and knowledge available to us to make certain we are doing everything practical to control one of the most serious situations that ever confronted New York employers.

Noise Measurement

A. L. CUDWORTH

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THERE ARE at least three reasons why industry is going to have to get into the noise measurement business. First there is a vast need for data relating noise exposure to hearing loss, and this data is going to have to come largely from industry. The second reason is that you can not make a hearing measurement program work without some controls on your testing rooms, and this is going to require measurements by industry. Thirdly, it is apparent that the bulk of noise control in industry is going to have to be done in industry by a step-by-step procedure that can only be evaluated through measurements made by your people in your plants.

In making industrial noise measurements, it is important that the data be both complete and accurate. Completeness is important in order that the noise sources under consideration be understood sufficiently well to evaluate the possibility of hearing impairment, and to point the way for methods of noise control. Accuracy is highly important and calls for a clear understanding of the operation of sound measuring instruments, and of their inherent limitations and weaknesses. I do not plan to go into any detailed discussion of noise measuring equipment other than try to point out how this equipment is related to what you are trying to measure.

Let us talk a minute about the procedure of a sound survey. You must realize that the procedure depends not only on the characteristics of the sound source, but also on the type of information that you are trying to obtain. Are you trying to evaluate hearing damage risks? Are you trying to evaluate speech interference? Or, are you trying to describe a noise source so that when you make noise control changes you will be able to evaluate how effective they have been?

The first two types of these surveys are basically the same. They require the same type of information. The third type of survey requires slightly different information, and consequently a different approach. I will go through an approach to these problems in terms of a procedure, which will help to standardize your technique for evaluating damage risks, or doing sound surveys for the purpose of making noise control engineering studies. First, however, let us review the type of noise sources that we encounter. We can break down all industrial noises into four categories. The first category is steady wide-band noise, and is the simplest type of noise to measure. An example of this type of noise is that found in the weave room of the textile mill, or in the vicinity of a ventilation fan or air jet. In general, you will find that in measuring this type of noise the sound level meter will indicate the same reading on both the slow and fast scales, and that an analysis of the noise can be made very easily using the octave band analyzer.

The second category of noise may be called steady narrow band noise. In this case, most of the energy is concentrated in narrow frequency bands. This is the sort of noise produced by circular saws, planers, or high-speed turbines. These operations involve high-speed rotating parts which generally produce a very narrow band type of sound. This type of sound requires a different approach and instrumentation, if one is interested in evaluating the noise source. By that I mean that if you want to say that this particular part of the machine is making a specific portion of the sound, you have to know a great deal more about the sound than just the octave band level. You must know exactly what the frequencies in these narrow band components are, and where they are originating. To do this, it is necessary that you restrict your analysis to a more narrow band width than is available in the octave band analyzer. You would usually find that this type of analysis is more easily carried out back in the office or laboratory, as the most readily available means of doing this type of analysis involves a tape recording of the sound and subsequent analysis.

The third category includes the types of sounds produced by impact forces and they are usually called impulse noises. This type of noise is associated with such operations as drop forging, explosions, etc. In this type of sound you will find that the peak sound pressure level, the maximum instantaneous pressure in the sound wave, may be a great deal higher than the reading that you will get if you use a normal sound level meter. Because of the ballistic characteristics of the meter movement, its indication on impact sounds will generally

be much less than the maximum pressure achieved. Therefore, you must go to more elaborate forms of analysis involving impact noise analyzers or oscilloscopes in order to measure the maximum instantaneous sound pressure occurring in such a pulse.

Again, I would like to point out that the use of an oscilloscope or an impact noise analyzer in the field is quite complicated and, in general, we find that the most satisfactory approach involves tape recording and analysis in the laboratory. However, the use of this much equipment can get quite involved and tape recorders are not really the answer to all of the problems. One quite often finds that when one gets back to the laboratory that the recording is incomplete or erroneous, and there is little recourse except a return to the field. There is a very complete discussion on the use of tape recorders by both Harris[1] and the *American Industrial Hygiene Association Industrial Noise Manual.*[2]

The fourth category involves the repeated impact noise and is the sort of noise present in the vicinity of riveting machines, machine guns, headers, punch presses, etc. This noise is in between an impact noise and a steady wide band noise. If the number of impulses is less than 50 a minute, you will probably incur errors in trying to use a sound level meter to measure such noises. If the repetition rate is over 200 impulses per minute, you will probably get valid results with the sound level meter. In between these two values, one should be very careful in evaluating the noise level on the basis of the readings obtained from a sound level meter. In this connection I might point out that the type of analyzer used by Crouch[3] for studying the distribution of level as a function of time is invaluable in this type of study. This type of instrument is capable of obtaining data that relates the energy level to the percentage of time that a specific level is present.

We might consider intermittent noise as being a fifth category in which the noise is varying in level and spectra from minute to minute during the day. For measurement purposes, however, we can consider this a mixture of the other categories that can be evaluated by making a larger number of measurements with the techniques already described. Again, one may find a tape recording system of invaluable assistance for recording the sounds for subsequent time distribution analyses. Assuming that you know what type of noise that you are dealing with and that you have considered the type of equipment necessary for your type of noise, what is a good routine for noise measurement? Again, we divide between a screening survey and a more complete survey that involves some type of frequency analysis.

If one is merely interested in making a rapid survey throughout the factory to determine hot spots, then one can do this with an overall indication or a sound level meter reading, bearing in mind that impact noises may lead to erroneous results. The next step is one of going through and making an octave band survey which will allow you to evaluate damage risk and at the same time give you more information on your control problems.

Before doing the actual measurements, there are a number of pre-survey checks that will help you determine the status of your measuring equipment. These procedures are covered very well in the equipment manuals, and basically involve checking the equipment to be sure that it is operating, and secondly doing some form of calibration. Again, I cannot overemphasize the fact that this data that you are going to correlate with hearing loss measurements should be sufficiently accurate to give us as close an approach as we can get to the dividing line between exposure and non-exposure. After turning the equipment on and checking the power supply or batteries, the next step involves calibration either acoustically or electrically. In general, calibration is a procedure that allows us to monitor the sensitivity of the instrument and at the same time adjust it so that correct readings are obtained. For the typical industrial plant having no facilities for microphone calibration, the most suitable approach involves electrical calibrations along with measurement of constant wide band noise, such as an air conditioning system, ventilating fans, etc. There are also available acoustic calibrators which enable you to monitor the sensitivity of complete sound measuring equipment, even when out in the plant making measurements. Of course, the calibrator is not fool proof. If dropped it will need re-calibration. However, by combining the acoustic calibrator with periodic measuring of some steady known noise, you can obtain a cross-check on the calibration equipment and at the same time monitor any changes in the characteristics of the instrument.

It is always wise to make an acoustical calibration prior to going out into the plant, since the familiar background conditions will not exist in the plant and you will be unable to compare the acoustical calibrator reading with the noise readings obtained from your standard or constant noise source. So, be sure that you do all of your checking in the office, under

familiar working conditions rather than waiting until you get out into the field to perform extensive calibration procedures.

In doing your measurements in the field, it is useful to get periodic calibrations. Usually four a day is adequate for most conditions. It depends a great deal upon the type of microphone you use and its temperature characteristics, the temperature changes in the plant, whether or not you are using a cable, etc. By calibrating periodically during the day you can eliminate these sources of error in the final data.

Let us discuss briefly the selection of measurement positions. Where do you want to take your measurements? Again, let us distinguish between two types of surveys, first the damage risk type of survey, and secondly, the noise control or engineering survey. If you are interested in just evaluating the noise exposure, the selection of measurement position is fairly simple, as it simply involves measuring the sound field where the personnel are stationed. Enough measurements should be made, however, to be certain of being able to evaluate exposure for all of the positions taken by the personnel and the noise sources. Also, care should be taken to make measurements under all operating conditions of machines causing the noise exposure.

The engineering type of survey involves specifying the characteristics of the noise source, and requires a great deal more equipment as well as a larger number of measurements. It is necessary to make measurements in a number of directions from the source if one is going to say how much sound comes out in various directions. I might point out that it is usually advisable to combine the two types of surveys if you are planning to do any noise control. You can usually utilize your noise control measurements for hearing damage risk evaluations.

In making engineering survey measurements there are several restrictions on how close to the source you should make you measurements. Again, these things are covered in the two manuals referred to above, and I will only briefly outline them at this time. There are nearly always a large number of noise sources in the vicinity of the machine that you are trying to evaluate in an engineering survey. Therefore, in order to evaluate the sound from a particular machine one has to get fairly close to it, in order to be sure that the sound is coming from that machine. Further, it is necessary to measure the background noise with and without the machine running, in order to be able to say how much of the noise is coming from the particular machine. One can also get too close to the machine which will give you information that does not lead to valid noise control recommendations. In general, one should keep close enough, however, so that you are not in the reverberant sound field or the noise field from other machines is less than three decibels below the noise you are trying to measure.

A second restriction has to do with the noise field in the vicinity of machines that produce narrow band noises. Those machines that produce pure tones will generally have standing waves in their vicinity, particularly in the presence of reflecting walls. There are techniques for evaluating the effect of these standing waves, and this requires a number of measurements in order to determine the average exposure or noise field characteristics of the machine.

Finally, the kind of data you want to record in any survey may necessarily depend on the problem but in any instance should be complete and accurate. If you are trying to make an evaluation of the damage risk you want to record a lot of other data besides just noise characteristics. You must record temporal characteristics of the sound, number of machines operating, time of operations, number of employees, etc. An example of information desirable in various kinds of surveys is shown in the noise manual referred to above.

The engineering survey, of course, requires a great deal more information in terms of particular sound source. For example, what are the horsepowers of the motors and what are the operating speeds of various parts of the machine? What are the noise contributions of various components of the machine? What are the maintenance requirements of the machines? All of these things help to evaluate your measurements later on when you think about control procedures.

In summary, I would like to say that there are fairly simple procedures described in existing publications and following them will enable you to make sound measurements for various types of surveys. More detailed information is also available. There is nothing mysterious about making sound measurements, but it does require a certain amount of skill and certainly a great deal of patience.

References

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Industrial Audiometric Measurements

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THE MEASUREMENT of hearing ability is the most important part of a hearing conservation program, according to the Subcommittee on Noise in Industry.[1] Both preplacement and periodic follow-up tests should be part of the program routine. The Subcommittee further states, "Any hearing conservation program without medical supervision must be considered inadequate."

It is the purpose of this paper to discuss briefly such questions as: How does one approach an industrial concern with this relatively new problem of industrial audiometry? What equipment and personnel are needed? Where can help be obtained? And, what are some of the major steps to be taken?

Selling Industrial Audiometry

To introduce an effective industrial audiometric program it must be sold to top management[2] so that management becomes a co-operative partner and an effective follower.

In preparing to sell the benefits of a hearing measurement program to industry, we must bear in mind that management in general is resistant to something new until it has proven itself. We can, therefore, expect to receive some opposition to suggestions we may make. Two major reasons why industrial hearing conservation programs have not been more widely adopted are: management's lack of knowledge regarding the basic problem and the fear that it may create an atmosphere in which many compensation claims for hearing impairment will be filed. Until these two are overcome, only limited progress will be made.

Laying the proper groundwork and acquainting management to appreciate the benefits of a hearing measurement program are steps which must be taken before co-operation from management can be obtained. Ability or know-how, is the prime requisite for accomplishing this. While no person can master all the skills required for hearing conservation, such as, acoustical engineering, physics, electronics, audiology, otology, and the applicable laws,[3] it is possible by proper study, training, and experience to become a "qualified interpreter," or one who can explain to management the mutual benefits to be gained by the employer and the employee from a well-rounded hearing conservation program. It must be pointed out to management that there are pitfalls which will be encountered sooner or later if such a program is not adopted. The fact must always be stressed that with the adoption of sound preventive programs everyone gains—the employer, and the employee mostly.

Experience has shown that the 16-millimeter sound films *Your Ear and Noise*,[4] *Approved Technique for Pure Tone Air Conduction Audiometry*,[5] and *The Effects of Noise on Man*,[6] are very helpful in enlightening management concerning the noise problems and aid in their solutions. Another effective educational tool is the *Guide for Conservation of Hearing in Noise*.[1]

When the employer becomes interested to the extent that there is general agreement at the management level that something needs to be done, the next step is to discuss the particular program required.

Hearing Evaluation

In order to obtain valid threshold audiograms, the following should be available: (1) Pure-tone audiometer, (2) Audiometric room or booth, and (3) Trained audiometric technician.

Pure-tone audiometer

The *Guide*[1] recommends for preplacement use only air conduction threshold tests made with a standard audiometer under specified conditions.

Attention should be called to the fact that hearing tests made by the whispered voice, spoken word, and watch tick, although still used, are inadequate for industrial use. Likewise the use of a tuning fork is unsatisfactory.

Pure-tone audiometers are either screening instruments or the diagnostic type. Screening instruments (not to be confused with screening tests) are sufficient for industrial audiometry. While speech audiometers and diagnostic instruments which have attachments for measuring bone conduction are important for otologists, they are not mandatory for the industrial hearing measurement programs. Standards for pure-tone audiometers have been set by the American Standards Association[7] and only instruments

meeting these specifications should be purchased for industrial use.

Automatic audiometers which permit the subject to make his own audiogram without the immediate attention of a technician have recently become commercially available. Since these instruments are relatively new, they have not been widely used in industry, however, they may gain greater acceptance as time progresses.

We should be mindful that all audiograms in some situations may be the basis of medicolegal problems, therefore, the proper equipment, environment, and testing techniques are very important. The recommended test frequencies for industrial audiometry are 500, 1000, 2000, 3000, 4000 and 6000 cycles per second. To meet local requirements, 250 and 8000 cps may be included. Information on the weights, powers, frequencies and prices of audiometers is shown in the *Industrial Noise Manual*.[6] Detailed instructions for the proper use of audiometers to develop valid audiograms are discussed by Glorig[8] and others.[5, 9]

Audiometric room or booth

If audiograms are made in the presence of excessive noise, it is difficult to determine whether the hearing is impaired or if the ambient noise has raised the threshold. The proper testing environment is, therefore, a vitally important part of any audiometric testing program.

Noise level surveys made by the writer in the environment in which industrial audiometry is sometimes performed has shown that, in many situations, the ambient noise levels were well above the published standards. This condition was also found in some doctors' offices.

In choosing an adequate testing environment the following procedure is recommended:

A. *Select a suitable and quiet location.* An audiometric room or booth should be located in an area as quiet as possible, preferably away from outside walls, elevators, heating and plumbing noises, waiting rooms, cafeterias, and busy hallways. The location selected should be convenient for both the employees and technician making the tests.

B. *Measure the prevailing noise level in the area.* The instruments used in measuring the ambient noise level at the selected location are the same as those used in making the plant survey; namely, a sound-level meter and an octave-band analyzer.[10] While making such measurements it is very important to consider the variability of the noise level throughout the day. If the highest background noise levels do not exceed the values listed in Table I, the test-room noises will not affect test results.[1] To obtain reliable over-all and octave-band readings trained personnel are required who understand sound measuring instruments, their operation, and their reactions to various external influences. In other words, it requires more than just meter readers. Personnel for making such noise level measurements are available to industry from several sources: (1) Specialists employed by insurance companies, (2) Industrial hygiene departments of the various states, and (3) Consulting acoustical engineers.

C. *Reduce the ambient noise level, if necessary.* In some situations existing conditions may meet the allowable background noise requirements, for example, some industrial storage vaults or x-ray rooms are so constructed and located that they meet the background noise requirements without alterations.

If the noise levels are found to be above the suggested allowable levels there are three general methods for securing a suitable room:

(1) Acoustically treat an existing room. In some instances it may be possible to obtain the desired noise reduction by this method. It may consist of sealing up cracks around doors and windows; sealing off or acoustically treating ventilation inlets and outlets; and applying sound-absorptive materials to walls, ceiling, and floor.

(2) Construct an acoustically designed room within a room. The ambient noises present in most industrial locations where an audiometric room may be located are predominantly of the low frequency type and, therefore, difficult to reduce. To obtain satisfactory results the design of an audiometric room must take into consideration three fundamental methods of noise control: namely, sound-insulating walls and doors that will permit little sound energy to be transmitted into the room from the outside; application of sound-absorptive materials to the walls and ceiling which will absorb sound

Table I

Suggested Allowable Background Noise Levels for Hearing Conservation Audiometry Rooms[1]

It is assumed: (1) no frequencies below 500 cps will be measured and (2) good-fitting binaural earphones will be worn.

Octave band cycles per second	300 to 600	600 to 1200	1200 to 2400	2400 to 4800	4800 to 9600
Level in db (C scale) re 0.0002 dynes/cm²	40	40	48	57	67

No levels have been set for the octave bands, 37.5 to 75, 75 to 150, or 150 to 300 cps. The noise in these bands has little or no effect at the recommended audiometric test frequencies.

FIGURE 1. Audiometric Room (Burgess-Manning Company, 5970 Northwest Highway, Chicago 31, Illinois).

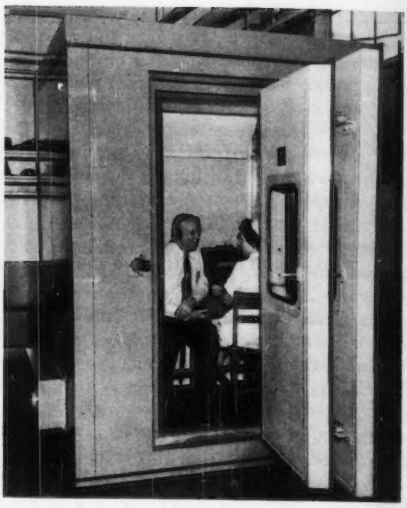

FIGURE 3. Audiometric Room (Industrial Acustics Company, 341 Jackson Avenue, New York 54, New York.

FIGURE 2. Audiometric Booth (Koppers Company, Inc., Industrial Sound Control Department, 200 Scott Street, Baltimore 3, Maryland).

TABLE II

Sound Pressure Levels Audiometric Room Burgess-Manning Company, Chicago, Illinois

	Overall Level db	Octave band levels—decibels							
		20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–10,000
Outside Room	No Readings								
Inside Room	53	52	39	28	19	17	18	17	12
Suggested Allowable Noise Levels for Audiometry Rooms	—	—	—	—	40	40	48	57	67

TABLE III

Sound Pressure Levels Audiometric Booth Koppers Company, Inc., Industrial Sound Control Department, Baltimore, Maryland

	Overall Level db	Octave band levels—decibels							
		20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–10,000
Outside Room	75	73	63	61	54	47	43	39	39
Inside Room	66	65	43	37	21	17	18	17	13
Suggested Allowable Noise Levels for Audiometry Rooms	—	—	—	—	40	40	48	57	67

TABLE IV

Sound Pressure Levels Audiometric Room
Industrial Acoustics Company, Inc.,
New York, New York

	Overall Level db	Octave band levels—decibels							
		20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–10,000
Outside Room	72	66	62	61	65	59	58	52	44
Inside Room	59	58	31	22	16	16	17	17	19
Suggested Allowable Noise Levels for Audiometry Rooms	—	—	—	—	40	40	48	57	67

entering the room; and use of resilient mountings to prevent transmission of vibration into the room. These three design factors are of a technical nature and are usually not well understood by the average individual assigned to build such a room. For the "do it yourselfer," an example outlining the design of an audiometric booth is given in the *Handbook of Noise Control*.[11] In most cases the best results can be obtained in building a room by employing an acoustical engineer.

(3) Purchase a prefabricated testing booth. It has been our experience that generally a prefabricated audiometric room or booth is the simplest and best solution to the problem of providing a good testing environment. These rooms or booths are available in various sizes and can be installed in most medical or first aid departments. The rooms vary in their sound insulation characteristics and when the manufacturer is provided with the sound pressure levels in octave bands at the proposed site, they will be able to determine the type and design most suitable.

Glorig[8] lists three manufacturers of prefabricated test rooms. Noise level readings for these rooms were made by the writer in industrial locations. Photographs and associated noise level readings are illustrated in Figures 1–3, and Tables II, III and IV.

D. *Retest the completed installation.* A retest is necessary to assure that the noise level readings are at or below the suggested allowable noise levels.

TRAINED AUDIOMETRIC TECHNICIAN

The audiometric tests recommended for use in industrial hearing conservation programs can be conducted by audiometric technicians; such as, a plant nurse, laboratory technician, personnel assistant, or other persons possessing sufficient aptitude and interest. Needless to say, such technicians should receive special training. The person assigned to make audiometric tests must be impressed with the fact that the work they do must be acceptable to the medical and legal profession who may have occasion to use the audiometric data.

This training requires at least 12 to 14 hours and should, preferably, be conducted by an otologist or audiologist and should include practice work with audiometer. Such training may be obtained at audiology clinics conducted by various universities, medical clinics, insurance companies, and private facilities. In all cases the industrial audiometric technician should work under medical supervision.

Summary

An important part of a well rounded industrial hearing conservation program is procuring valid threshold audiograms. These may be obtained by employing a medical consultant who supervises a trained technician working in a suitable testing environment with a standard audiometer.

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Hearing Conservation in Wisconsin

ROGER B. MAAS, M.D.

IN SPITE of the recent nationwide attention given to the noise problem, and its great economic significance, it should be remembered that factory noise contributes only a very small part of the total hearing loss found among our nation's workers.

Previous to my work in industry, I was in charge of hearing conservation in the Wisconsin Public Schools, sponsored by the Wisconsin State Board of Health, to locate children having hearing losses in our classrooms. Our complete audiometric surveys indicated that between five and ten per cent of these children had hearing losses. Three out of every 100 children were in need of medical care for their hearing. Communicable disease, congenital deficiencies, hardened wax, accidents and injuries were found to be responsible for many of these childhood hearing deficiencies. It is also a well-known fact that there are over 100,000 children attending day schools for the deaf in the forty-seven states having these training institutions.

The Veterans Administration recently reported that in 1956 it was spending $60 million per year for approximately 90,000 veterans with service-connected hearing disabilities—and you and I are helping to pay for this. A very conservative estimate by the United States Public Health Service indicates that between 10 million to 12 million people need hearing aids. These facts illustrate to some extent the magnitude of the problem of deafness regardless of cause. It should be added that all of these persons are potential workers who will knock at the gates of our factories for jobs.

It is estimated that in the State of Wisconsin 27 out of 100 newly hired workers have hearing losses at the time of their initial employment. For this reason some of the laws governing compensation for hearing loss contain the following provision: "In the absence of pre-employment audiometric measurement which determines the condition of hearing before employee starts work the last employer pays the accumulated hearing loss."

The record then serves as important economic protection for the employer and the employee as well. However, the audiometer makes another very valuable contribution to a total program of hearing conservation. It is the method by which we gauge the effectiveness of our noise reduction or engineering control efforts, and is also the real test of the effectiveness of personal hearing protection devices because the audiogram indicates just what the worker's status of hearing is at any time.

Audiometric examination is the only way we have presently to detect a person susceptible to noise exposure. By comparing the audiogram charts taken at intervals we know just how well the person is bearing up under the strain of noise. If the hearing acuity continues to decrease in spite of noise reduction measures and personal protection efforts, this record may tell us that he must be taken out of his noisy environment.

It is well for us that the early noise-induced loss of hearing is indicated at the higher frequencies, at about the 4,000 cps frequency level, long before they are noticed by the individual and long before they cause disablement. By showing a worker his personal record of hearing acuity we have a most effective motivating device for ear protection.

Because of the many uses for audiometric data, it is felt in Wisconsin that proper facilities readily available will insure quantities of highly reliable information. Figure 1 illustrates the number, type and location of audiometric facilities in the State of Wisconsin. The circled areas contain the large industrial centers. The coding of this figure indicates whether hospitals, private physicians or other organizations have the facilities for the measurement of hearing. At present there are just under 300 installations over the State of Wisconsin where audiometric examinations can be made.

An attempt has been made to include the hearing measurement as part of the pre-employment and periodical physical examination, and this has turned out to be a most successful venture. One distinct advantage of this method is to make the hearing evaluation a portion of the total information a physician requires when one is examined. As a by-product to this approach it has tended to enhance the desirability of the physical examination program, and we have added much as a result of the emphasis on hearing. Physicians have become quite willing to assume the cost of the examination room and the audiometer as well as the responsibility for seeing that the technicians are properly trained.

In some instances, in small communities, the doctors have agreed subsequently to set up a

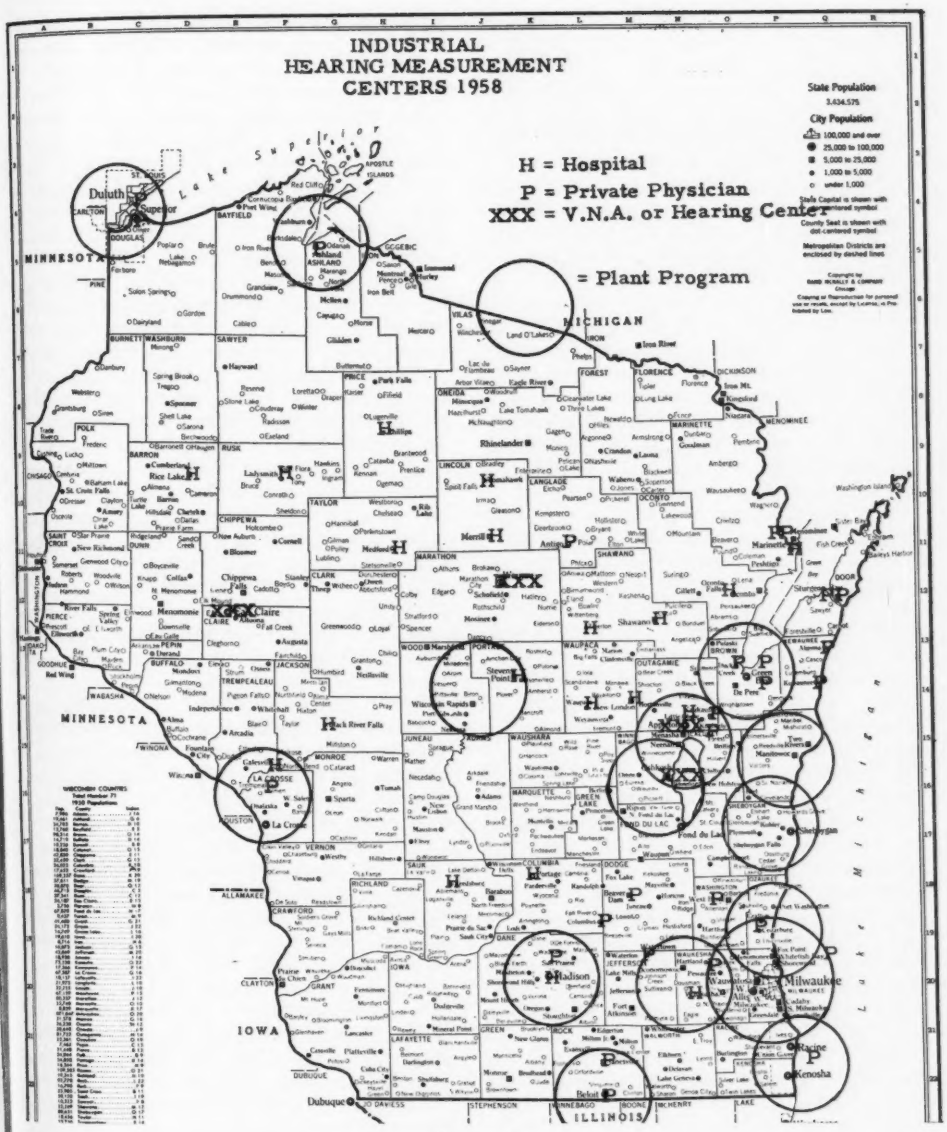

FIGURE 1.

single community facility in the local hospital. The hospital setup in the small community for audiometric measurement is gaining rapid popularity, one of the reasons being that some spot can be usually located where quiet conditions prevail without the additional expense of an audiometric examination room or booth. However, many of our hospitals still find it well worth the cost. A likely spot in the normal hospital is the x-ray room which is lead-lined, usually in the basement and away from traffic.

Another advantage of the hospital facility is the natural arrangement for out-patient service. Appointments can be made in advance usu-

ally by telephone in the usual manner and there are also several technicians on duty at all times to administer the examination properly. Because most physical examinations include the x-ray, the employee is not making a special trip to the hospital, and the evaluation becomes a very natural and normal undertaking.

Through the stimulation of industrial hearing conservation many communities now possess facilities for checking hearing which did not have them previously. Physicians are utilizing the special out-patient service for the benefit of the entire community. For example, pre-school children coming in for their physical checkups sponsored by the PTA organizations and others recommended by school teachers as those having learning difficulties are now able to have the hearing factor checked without waiting for itinerant technicians who come in only periodically. This is often used as a selling point to get the doctor or hospital interested in the establishment of a hearing measurement center. Many of the plants in our smaller communities have purchased the audiometer and presented it to the hospital for this very reason.

Establishing the hearing measurement facilities in the industrial plant is usually easier to do once management is convinced of its value. This is due to the fact that most large industries have existing medical departments or industrial nurses. It would seem advisable not to do this unless there were in the neighborhood of 125 to 150 employees and especially in places where there is little labor turnover and new hires chiefly due to the expense of the necessary equipment and personnel. In these instances the other methods described previously would be more economical.

In Wisconsin we have many large plants employing consulting otologists on a retainer fee basis to guide the progress of the program and to act as consultant and supervisor to the audiometric technicians. This arrangement is probably ideal because the otologist interprets the audiogram data, directs the periodical re-check program, counsels with workers having hearing losses, conducts otological examinations and advises on matters of personal hearing protection. This arrangement saves time and money when the number of employees warrant it. Employing a physician who has this interest in industrial hearing conservation pays great dividends in more functional hearing conservation activity.

Now, how does one get a small community aroused and interested in setting up these services? Fortunately for us in Wisconsin we have a very active State Medical Society, the University of Wisconsin Extension Division, the Wisconsin Association of Manufacturers and the Wisconsin Safety Council, who cooperatively sponsor regional or area conferences and discussion groups on the problem. First of all, the State Medical Society appointed a special committee which provided us with a guide entitled *Recommendations in Reference to Conservation Programs in Wisconsin.* This served as a blueprint or a map to get us going. Since that time the American Academy has gone into this and provided us with even a more complete guide eliminating the necessity to have one of our own.

Four years ago my own community of approximately 30,000 population organized a special hearing conservation committee in our local Chamber of Commerce which purchased an audiometer and built an audiometric examination room, which was located in the local Visiting Nurse Association building, then arranged for the training of the nursing staff in order to do reliable and valid audiometric examinations. Each participating member of this special hearing conservation committee of the council representing their particular industry agreed to pay $2.10 per audiogram. As most of the plants hire probably less than fifteen employees a year it is looked upon as being a very favorable arrangement. The idea has spread to many non-noisy places of work because of the community interest stimulated in hearing.

Specific questions relating to details of administering or establishing of a facility, such questions as the type of audiometer to buy, the questions pertaining to the training of technicians can be answered by area otologists, members of the AAOO. It should be remembered that no audiometric measurement for the hearing conservation program is complete without medical supervision and counsel. We regret to say that in our state this is one of our shortcomings, but each year we are doing better than the year before.

There is obviously a great deal of promotion work connected with the development and expansion of this state wide audiometric program. Many groups including the Wisconsin Safety Council, University of Wisconsin and the Wisconsin Manufacturers Association have been instrumental in such work.

The result of five years of hearing conservation activity in Wisconsin has been more than gratifying even though there is still much to be done. First of all, the majority of our plants have hearing conservation activities in progress. A few still are skeptical and haven't budged because of fear of potential claims.

So far the present laws pertaining to hearing loss have remained unchanged since July 1, 1955. It appears that labor and management are quite well satisfied with the way things are going, and

it does not look like there will be changes in the near future. There have been some claims, but with the present six-month waiting period in effect, not too many. The labor unions so far have given enthusiastic support to hearing conservation efforts.

The results of our noise control activities have been excellent. A large percentage of our plants are engaged in some phase of noise control. Here again the University of Wisconsin through its Industrial Management Institute activities, comparable to the activities here performed by your association, the Associated Industries, is conducting noise control clinics and conferences which are well attended and which pay off in more quiet working environments, which is the real and final answer to the noise problem.

Wisconsin machinery buyers are already demanding from manufacturers and designers improved equipment that will not cause excessive noise. There are high hopes for the future in what our machinery designers can do for us.

Likewise, efforts at hearing protection, the use of ear plugs is continuing to grow, but not without discouragement. It is felt that ear protection is a long-range educational project because the average worker accepts noise as a normal part of his occupation and is not too worried about the damage he may suffer fifteen to twenty years from now. Workers don't seem to be satisfied or won't continue to wear protection unless noise levels are excessively high or very annoying. It is much the same attitude that people have toward Civil Defense. What do we care about what happens tomorrow? We are not giving up on this phase of helping conservation. Instead we are constantly seeking new hearing protection equipment; new methods of making each man realize what he stands to lose if he does not protect himself now. Because of the relative newness of this phase of personal protection it is hoped that some day our effort will be equal to that of eye protection.

The weakest link in our total effort to conserve the employee's hearing is to get the employee to the ear physician, the otologist, either because we do not have enough trained men available or because the employee doesn't care enough to go. It is felt that an effective program cannot exist without medical follow-up. When the doctor is in the picture we get better results, greater interest, more hearing protection equipment worn, better attitudes, and more hearing preserved.

Figure 2 happens to show one of the plants that I visit. This otologist is employed on a retainer fee basis. He is looking in the ears comparing what he finds with the audiogram. The doctor then gives the worker a "pep talk" on

FIGURE 2.

ear protectors. We find that this is most helpful because when the doctor tells you to wear ear plugs, shows you the audiogram and tells you what you stand to lose, you don't consider that lightly. You do something about it. It is a doctor's prescription. That is why we emphasize so much the role of the physician in all hearing conservation activity.

Figure 3 shows a card which is given at the time of the hearing measurement to help workers get to the doctor. This is a very simple device. The fellow's name is on it and it is checked in square 1 or square 2. They are pretty happy when they can come home and show their wives the card indicating that their hearing is normal or satisfactory at this time. She is apt to demand action when the other check indicates that it did not fall within the limits of normalcy and a trip to the doctor is advised. This was initiated at the suggestion of a doctor, and it is working out very well. This device has developed great interest. Many of the physicians in my own community will show me a number of the reporting cards which the employees have brought to them much in the same way that the schoolchild will bring home an examination report from the school nurse.

The hope of getting each man possessing an abnormal audiogram to the physician still remains in the future, but our batting average increases each year. Because the real rewards of hearing conservation efforts, like other human conservation activities in which we are engaged, lag behind our interest in natural resources which lie far in the future as well, it is too much to expect great fervor or excitement on the part of workers to do all of the things that should be included in any effective hearing conservation effort. But we take some comfort from the fact that we are trying. Something is being done today to keep our workers' hearing intact.

We like to think some day that our workers will not be coming back to us saying, "Why didn't you tell us about ear plugs," or "Why didn't you do something to help us?" If we set

To: _____
(Name)

The Hearing Measurement you have just had indicates that:

☐ Your hearing is normal and satisfactory at this time.

☐ You need a further check by an otologist or ear specialist of your choice. (In the interest of preserving your hearing, it is recommended that you make this appointment as soon as possible.)

_____
(Technician)

_____
(Station) (Date)

"HEARING IS PRICELESS - PROTECT IT!"

304-721 10-56

FIGURE 3.

up the necessary effective hearing conservation effort now and stick with it they won't ever be able to say this. Occasionally our company receives a letter from the wife of an employee who knew that we have had a hand in the effort to conserve her husband's hearing. The most recent one went something like this: "Thanks for getting my husband, Albert, to the ear doctor. He now has a hearing aid and is acting like a human being again."

I know it is easier today to count the number of people who resist our help probably because they make more noise than it is possible to count the numbers who are accepting and receiving help, but the road ahead still looks encouraging. Certainly, through the establishment of functional hearing conservation programs in your state and mine, we are not only guarding our economic welfare, which is the primary purpose of our being here today, but we shall also contribute to the health, the welfare and the happiness of our fellowmen.

Controlling Exposure to Industrial Noise

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WHENEVER a problem develops in any field, the usual first step is to subdivide it into its component parts. The next step is to assemble the parts, based on scientific facts, into a refined situation. Frequently, such an approach will simplify both the problem and its solution.

It is the purpose of this paper to introduce the subject of industrial noise control and to discuss briefly the basic methods of noise reduction and worker protection. In presenting these basic principles, it is not the intention to over-simplify either the industrial noise problem or noise control procedures. Rather, it is intended to introduce the first step in noise control. Therefore, it is hoped that this may suggest some practical approaches to protection against excessive noise exposures and, perhaps, introduce the more specific methods of control which wi'l follow.

Noise Control Standards

Whenever it is desired to control any hazard, bench marks must be established as a guide in designing the control method. In other words it is necessary to know how much control is needed. In the industrial hygiene field we have maximum allowable concentration (MAC) values which are used as guides for health protection. For example, if average concentrations of lead dust and fume are maintained below 0.2 milligram per cubic meter of air, it can be reasonably assumed that exposed workers will be protected.

The 0.2 figure is a guide to engineering control and gives a basis for design of new ventilating systems. If the MAC figure were less than 0.2, the design requirements would be much more strict and the cost of the installation would be

higher. If the MAC figure were greater than 0.2 the design requirements would be less severe and control costs would be decreased.

In the case of industrial noise, specific damage risk criteria have not been established. However, more information is gradually becoming available and from these data it should be possible to establish tentative design criteria for worker protection.

Bench marks or design criteria are very important in industrial noise exposure control, since a decrease of one or two decibels in the criteria could mean an increase of hundreds or even thousands of dollars in the cost of the control installation. In fact, the cost of control increases approximately four times as the factor of noise reduction accomplished is increased by one. It seems doubtful that we will soon have precise damage risk criteria for many types of industrial noises. This does not mean that reasonable control cannot or should not be undertaken, because considerable progress can be made on the basis of present knowledge.

Basic Methods of Control

Until recently, noise control for worker protection generally was not practiced in industry. Most of the advances in this field had been made in quieting offices, hospitals, and schools for the purpose of improved comfort or communication. However, the same basic principles can be applied for the control of noise in industry. These basic principles are:

A. Quieting the source. Dusts, fumes, vapors and gases are most effectively controlled at the point of origin. So are the greatest benefits in noise control derived from quieting the source. This can be accomplished through original machine design, redesign after installation, or machine maintenance. The ideal approach, of course, is noise reduction through new machinery design.

Some equipment manufacturers have made outstanding accomplishments in this respect. However, many of these noise reduction jobs have been accomplished with items sold to the public. Such items include automobiles and home appliances. In the future, purchasers of industrial equipment will demand quieter machines, and designers and suppliers will be forced to give consideration to noise control in addition to meeting the usual specifications.

As industry recognizes and evaluates its noise problems, it will be in a better position to make changes in existing equipment that will be favorable to noise reduction. Gear noises, loose bearings, noisy conveyors, escaping compressed air and steam, and similar noise sources can be quieted at the source through engineering and maintenance department changes.

B. Substitution of less noisy operations or machines. Substitution of materials, equipment or processes is an effective means of controlling any type of hazard. This approach, however, may have limited application in noise control since in many cases it may not be possible to provide control without eliminating the product.

On the other hand, there are certain areas where substitution may show considerable promise. Typical examples of this method include substitution of squeeze type equipment or welding for conventional riveting, and chemical cleaning of metal for high speed polishing wheels. The engineering departments of industry should be in an advantageous position to consider this method of noise control in its routine activities.

C. Isolation of noise source. Frequently, a single operation or process in a large department may be responsible for the hazardous noise exposure. In such cases, isolation methods of control may prove effective. This involves moving or locating the process in an area where a minimum number of workers would be exposed or isolating the source in a room. Constructing a wall or other barrier between the source and the exposed workers is another approach to isolation. If the isolated equipment requires an operator, personal protective equipment can be provided.

Another type of isolation involves increasing the distance between the noise source and the exposed worker. The application of distance to worker protection is simple in theory, but it can be effective in many industrial situations. This method would be applicable especially during original plant layout or when equipment is being relocated.

Reduction of noise exposure by increasing distance follows the inverse square law. Thus, by doubling the distance from the source, the sound intensity is reduced to one-fourth of the original intensity. Tripling the distance reduces the intensity to one-ninth. In more practical terms, a 60 decibel exposure at X distance would be reduced to a 54 decibel exposure at 2X distance.

D. Isolation of the worker. Isolation as a method of noise control is similarly applicable to the exposed worker. In situations where the number of operators is small and the nature of the process is favorable, isolation of workers in a separate room is effective. This method has been observed in chemical processing, power and metal products plants as an effective employee protection procedure.

E. Noise control by absorption. When noise is produced at a sound source, sound waves travel outward in all directions. When the sound

waves encounter other machinery or walls, they are reflected in the same manner as light. As other surfaces are encountered, the waves are again reflected. Thus, every part of the room almost immediately is filled with sound waves traveling in all directions. These multiple sound reflections have the effect of increasing the over-all sound intensity. The total intensity will equal the sum of the direct and indirect sound. In this way, the reflected sound contributes materially to the total noise exposure.

If sound absorption material is applied to the walls of the room or otherwise installed for noise reduction, at least part of the noise exposure caused by reflected sound waves will be controlled. This method has limited application to the control of employee noise exposures, since it has no effect upon the direct noise exposure. The maximum benefit will be derived from the absorption of reflected sound only.

F. Reduction of exposure time. In atomic energy installations, exposure to external radiations is limited to 300 milliroentgens per week. Various methods are used to measure total exposure to radiation and when the exposure exceeds 300 milliroentgens per week, the worker is not permitted to work until the average weekly exposure is reduced to below permissible levels. In the case of serious accidental radiation exposure, the time away from the job might conceivably extend to several weeks. In a similar manner, the total exposure of workers to noise can be reduced by removing the worker from the exposure a given period of time each day, or by transferring him to a quiet area in order to average his daily exposure.

The situation in noise does not directly parallel the radiation exposure example because the relationship of noise exposure to hearing damage has not been so accurately determined. However, since there appears to be a relationship between hearing damage and the quantity or mass of the insult to the hearing organ, this method offers an area of investigation for controlling hearing loss.

G. Insulation. The use of machine mountings insulates the equipment and reduces the transmission of sound to the floor and walls of the room. This method of control can be effectively used, especially in conjunction with the other methods discussed above.

H. Personal protection. The use of respiratory protection against dusts, fumes, vapors and gases usually is considered when hazardous conditions are temporary or when engineering control is not practical. Under similar conditions, the use of ear protectors, ear muffs or helmets would be considered desirable for worker protection against noise hazards.

There are certain processes and operations in industry which do not lend themselves to the application of engineering quieting procedures. For example, there is little prospect that pneumatic chipping can be quieted at the source, and generally accepted methods have not yet been developed which would allow for a quiet process. While it is possible that these operations might be segregated or isolated, the operator would still be exposed to high noise levels. Thus, the only control for the operator is suitable ear protection.

The control afforded by the various ear protection devices on the market will vary considerably. It has been reported that 25 to 40 decibels attenuation in all frequencies might be expected from insert type protectors if properly fitted. Thus, 25 decibels or more reduction in worker exposure will probably provide sufficient protection for workers in a large percentage of situations found in modern industry.

Summary

In summary, I should like to make the distinction between noise control methods and worker protection against hazardous noise exposure. On the one hand, noise is eliminated or reduced by the application of engineering methods. On the other hand, noise may or may not be eliminated or reduced, but certain steps can be taken to reduce worker exposure.

In this discussion an attempt has been made to briefly outline the basic principles of noise exposure control. It is apparent that these principles are not complicated and their application falls within the operational scope of the engineering departments of most plants. Many noise problems can be solved simply and at moderate cost, but industry must first have the desire or incentive to study its problems and develop a program to fit the needs.

Punch Press Noise Control

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QUIETING of punch presses by other than total enclosure or isolation is generally regarded as a monumental, practically insurmountable task. This attitude, from my observation, is the prime reason for so little having been done on it. Most press designers, as well as mechanical supervisory personnel in routine operations, apparently have concluded that the contact of the punch and die on the production material is the one significant noise source in punch press operation. This is not necessarily true. Frequently, other components are responsible for equal or greater sound pressure levels, particularly with the automatic units.

It is not meant to infer that we have overcome the problem of punch press noise. Rather, this discussion is in the nature of a progress report of our abatement work. These experiments resulted in readily perceivable reductions but much more detailed work is to be done. The purpose of this report is to point out some popular misconceptions on extent of the various noise sources in automatic punch presses in the interest of being helpful to others with similar problems.

Punch presses, of course, account for a major portion of the overall noise in metal container manufacture. They are used for fabricating the tops and bottoms of cans. The most common types are automatic and operate at speeds in excess of 200 strokes per minute. Typical of these is the single-die strip feed press. The strips of plate fed into the press are cut from oblong sheets as illustrated in Figure 1, which is a typical layout for shearing the plate with scrolled edges for convenience and maximum economy.

The strip feed press, shown in Figure 2, is fed the scrolled strips of plate from an inclined stack or hopper. The strip is moved progressively (by means of vacuum pick-ups) across the press unit under the punch which stamps out the circular ends at the rate of 300 per minute. Accessory equipment of the press includes: the feeding mechanism which is powered by the main motor of the press; a scrap ejector, powered by a separate motor, which strips the waste plate or skeleton mechanically and tosses it into a hopper; the product or end ejector which removes the ends from the die mechanically; a mechanically driven lubricating system; and a directly connected but separately powered "curler" unit which puts a flange on the edge of the stamped circle of plate by rotary squeezing action.

In evaluation of the various noise sources, the individual machine components causing noise were isolated as much as possible by disconnecting or removing all other noise producing parts. The noise radiating from the component under study was then measured using a sound level meter and octave band analyzer. The microphone was placed at a distance of six inches from the source in such position as to pick up grazing incidence of the noise so as to avoid necessity of microphone directional corrections.

In contrast to the common assumption that the only significant noise source is that of punch and die contact, 36 definitely assignable noise sources were isolated by this procedure. Eight of these contribute noise levels of 90 db or more and are listed in Table I. All tests were taken with the microphone located six inches from the noise source. The range of punch-in-die noise recorded is not an indication of fluctuation of sound pressure levels but of direction from the source. For example, 92 db was measured six inches directly below the die pin plate while 108 db was measured six inches directly above the die. Noise at any one specific location remained constant under the test conditions.

After evaluating magnitude and character of the noise from the various sources, a few of the more obvious and simple quieting measures were tried. These were of the type that could be added to the press rather than any fundamental redesigning or change of production operations.

A cover was made to close the space in the main frame under the die. This was fabricated from 16 gauge sheet steel lined on the inside with one-inch fiberglass blanket (Figure 3). The edges were gasketed with one-half-inch sponge rubber to form a tight seal. At a spot six inches below this cover, when installed, the noise reduction obtained was 13 db.

A similarly fabricated cover was made to enclose the operating ram parts above the die as much as possible. However, it was necessary

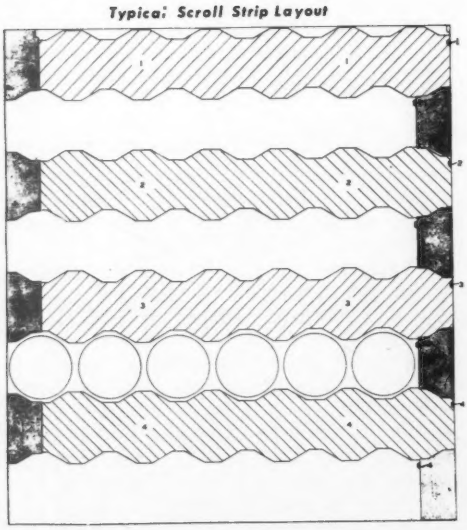

FIGURE 1. Typical scroll strip layout

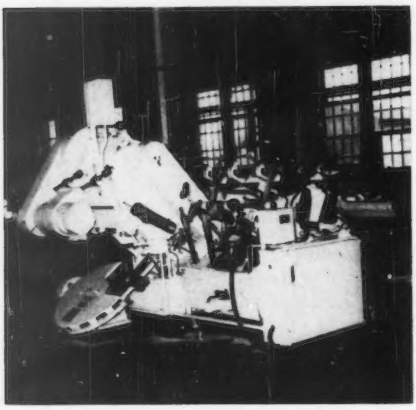

FIGURE 2. 401-142 Strip feed press (rear view).

to leave openings for strip feed, scrap ejection and the ram crankshaft. These openings, of course, allowed escape of noise with the result that this latter cover caused a reduction of only 2.5 db in the punch-in-die noise measured at a spot six inches above the cover.

Another attempt to quite the punch-in-die noise was by isolating the die from the frame of the machine, since much of the noise is caused by sympathetic vibration of the main frame casting. The bolster block under the die was shaved down one-half inch and this space filled with a Fabreeka pad cut to the appropriate shape. This resulted in only one db reduction

TABLE I

Major Sources of Noise
in 401-142 Automatic Strip Feed Press

Punch-in-Die	92-108 db
End Ejector	104
Feed Cam Drive Gears	102
Overhead Stripper Bumper	95
Feed Cam and Rollers	95
Knock-out Cam And Punch Ring	94
Feed Side Drive Chain	90-94
Scrap Ejector (rolls touching)	90

FIGURE 3. Cover for space below the die (inside view).

when measured above the die. Doubtless additional reduction could be obtained by using a softer material than Fabreeka but this involves too much risk of die misalignment.

The noise of ejection of the product or end is caused primarily by the cam following the roller on the ram and secondarily by vibration of the kicker arm. Modification of the profile of the end ejector cam (Figure 4) to reduce sharpness of the kick was found to result in 7.5 db noise reduction when measured six inches from the operation. Other possible methods which might be used for removing the ends from the die with less noise are: air pressure, air piston movement, rotary arm or spur wheel, magnetic device. We have tried none of these latter methods to date.

The stripper bumpers also rank high as a noise source. These bumpers limit the downward motion of the scrap stripper after the punch has cut through the plate. A second bumper acts as a stop for the return motion of the stripper. These bumpers are metal and the sound generated by metal to metal contact was measured at 95 db at a point six inches away. Simply inserting rubber washers over the bumpers (Figure 5) resulted in 8 db reduction.

A reduction of 10.5 db six inches away from the side of the feed cam drive gears was ob-

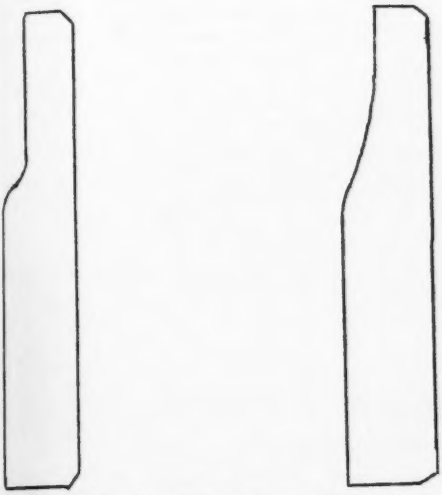

FIGURE 4. Profile of end ejector as furnished on the press (left), and as modified (right).

tained merely by modifying the latch for the coverguard so that it made a tighter seal. The feed cam and rollers were quieted 3.5 db by substituting larger rollers, reducing the 0.011 inch play between cam and rollers to 0.002 inch.

Figure 6 shows the press with the shields in position below and above the die. Operators objected to the upper shield since it eliminated ready visibility of the die. Since it did little good because of the necessary openings, it was discarded.

Table II summarizes the original noise and that measured at the same spot (six inches from the source) after these simple quieting measures. The overall reduction of press noise in the operator's normal hearing zone near the scrolled strip feed hopper with all these quieting measures in use during can end production was 8.5 db (99 down to 90.5). Calculations showed that approximately 79% of the reduction was due to only three of these quieting measures: (1) the shield under the die, (2) the rubber washers on the stripper bumpers and (3) the modified profile on the end ejector cam. Although these three measures are only a partial job they were considered sufficient to try on production presses in a plant.

From this experience to date it seems that the greatest reduction in press noise will result from basic design changes. However, the potential benefit of little, simple things such as those mentioned herein should not be overlooked. Obviously, it is unlikely that manufacturers will discard their present punch presses just because they are noisy and particularly when new presses on the market show no great improvement in this respect.

The recommended procedure for quieting of

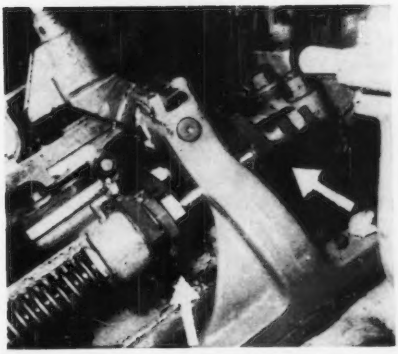

FIGURE 5. View of overhead stripper bumper with bumper rubbers in position. Photo also shows modified end ejector cam.

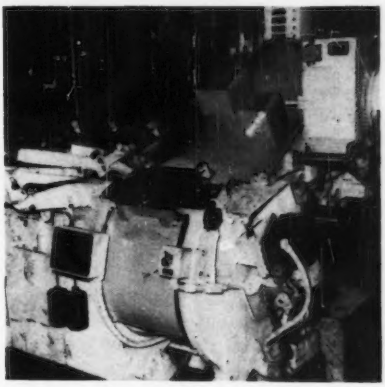

FIGURE 6. View of press with both covers in position.

TABLE II

Noise Levels from Various Sources Measured before and after control modifications

Noise Source	Overall Noise Levels, db	
	Original	Abated
Punch-in-Die	100	88
End Ejector	104	96.5
Feed Cam Drive Gears	102	91.5
Overhead Stripper Bumper	95	87
Feed Cam and Rollers	95	91.5
Knock-Out Cam And Punch Ring	94	91.5
Feed Side Drive Chain	94	91.5
Scrap Ejector	90	90

a press or any machine (short of isolation) is:

(1) Find the sources of sound radiation.

(2) Determine which of these is most important.

(3) For this sound source, identify the source of sound energy and try to reduce it, i.e., reduce the impact, improve the class fit, reduce friction by better lubrication, etc.

(4) Find the coupling between the source of sound energy and the radiating source and determine whether decoupling is possible. For example, put a vibration-absorbing type material between the parts.

(5) Increase the mechanical impedance of all moving parts by increasing the mass, stiffness, or damping properties.

(6) Study the problem of noise radiation and how to diminish it by such means as lowering the frequency of radiation, reducing size of the radiating surface, removing baffles or partially enclosed one-opening spaces in order to produce a dipole as opposed to a simple source, or enclosing the object.

(7) Incorporate the accomplishments into a new design and preceed to the next most important noise source.

Product Quieting of a Pencil Shaping Machine

LAYMON N. MILLER and ROBERT M. HOOVER

Bolt Beranek and Newman Inc.

THE S. A. Woods Machine Company, manufacturers of wood moulding and shaping equipment, has recently undertaken a noise reduction program for some of its wood processing machinery. One particular pencil shaping machine has been used to evaluate some of the noise control treatments which may be applied later to some of the larger equipment. In this paper we wish to review some of the noise control work which is now being carried out experimentally on the pencil machine.

The early steps in the manufacture of pencils are shown in Figure 1. Cedar slats are first planed to proper dimensions and grooved for pencil leads. Leads are then laid in the grooves of one slat, and a second matching grooved slat is cemented over the top of the first to form an assembly ready for the pencil shaping machine.

A standard model S. A. Woods pencil machine is shown in Figure 2. Glued slats are stacked in the hopper at the right and are fed continuously by an automatic feed mechanism into two cutter heads rotating at the high speed of 10,200 rpm, or, as in the case of the actual machine used in this program, as high as 14,400 rpm. The upper cutting head cuts out the top profile of the slat to form the upper half of eight pencils lying side-by-side (see upper inset of Figure 2). This is then fed into the lower cutter which cuts out the lower profile of the slat and separates it into the completely shaped pencils which are then conveyed from the left of the machine (see lower inset). Under typical operating conditions one machine can produce up to approximately 1200 pencils per minute or 20 pencils per second.

Each cutter head has two cutting blades having an effective diameter of approximately five inches. The tip speed of the cutter blades is approximately 300 feet per second which is about 0.3 the speed of sound in air. The blade passage frequency is 480 cycles per second, which is obtained as follows:

Blade passage frequency
$= (14{,}400 \text{ rev/min} \div 60 \text{ sec/min}) \times 2 \text{ blades}$
$= 240 \text{ rev/sec} \times 2 \text{ blades}$
$= 480 \text{ blades passages/sec}$

When these blades rotate at high speed, a siren-like whine is produced by the "chopping" of the air with the cutter blades. Where the rotating blades pass close to guide plates or other parts of the machine, the "chopping" effect is pronounced and the noise is more intense. Under normal operating conditions the overall noise level at the operator position reaches approximately 110 to 115 db, with the peak of the noise falling at the blade passage frequency of 480 cycles per second.

In the evaluation of noise control treatments for this machine, only the top cutter head has been operated and wood stock has not been fed into the cutter. The measured noise levels, however, are representative of complete machine operation.

Figure 3 shows the average noise levels meas-

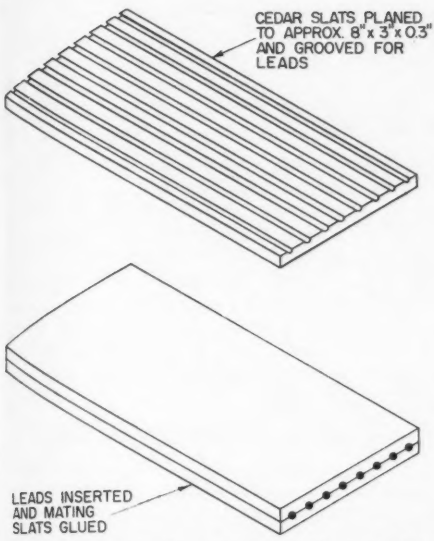

FIGURE 1. Steps in the preparation of pencil slats.

ured at four positions around the machine, each position located four feet from the upper cutter head. The solid curve at the top gives the noise levels for the cutter operating in the open with no enclosure around it. In actual practice, a small hood is placed just above the cutter through which wood chips and dust are drawn off with an exhaust fan. This hood has considerable open area, however, through which sound can radiate; so it provides very little noise reduction. To demonstrate the value of closing up all the open cracks around the hood, a specially fitted hood was made and completely sealed over the cutter head. The noise levels at the four-foot positions measured with the cutter operating inside the sealed hood are shown by the lower dashed curve of Figure 3. It is seen that the sealed enclosure provides over 25 db of noise reduction in the octave frequency band that contains the 480 cps peak signal.

To show the effect of a small air opening in the enclosure, an area of three square inches was opened in the front face of the hood. The noise level four feet in front of the machine then jumped up to 105 db at the peak frequency. This was only a few db lower than if there were no hood at all. Thus, we see the necessity for closing all cracks to a minimum and acoustically treating all necessary openings.

There are four necessary openings to each cutter head. There must be one opening to feed in the stock, a second opening to discharge the cut stock, a third opening through which wood chips and dust are exhausted with a fan, and a fourth opening to provide an adequate supply of air for effective removal of the wood chips and dust.

The openings for the intake and discharge of wood stock can be kept quite small in this machine because the stock may be counted on to fill up most of the open area. Cracks around the edges can be so treated that the noise which escapes can be partially absorbed and partially deflected away from the operator.

The openings for air intake and chip exhaust are required to be approximately 20 in.^{2} in cross-section. For these relatively large openings, acoustically treated mufflers must be provided to limit the escape of noise. An exhaust muffler was actually installed on the hood for the measurements given in Figure 3. That particular muffler provides approximately 20 db of re-

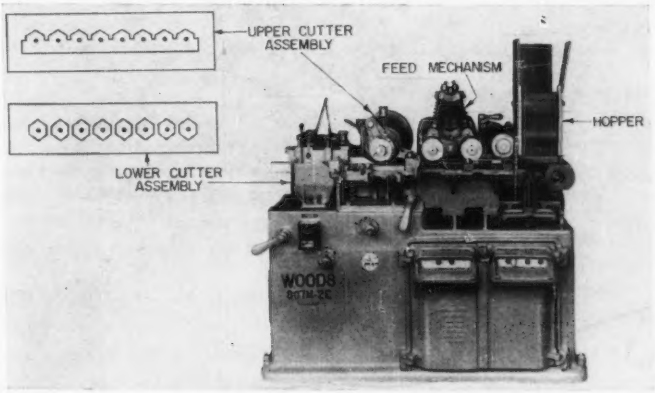

FIGURE 2. S. A. Wood's Pencil Machine with insets showing profiles resulting from upper and lower cutter heads.

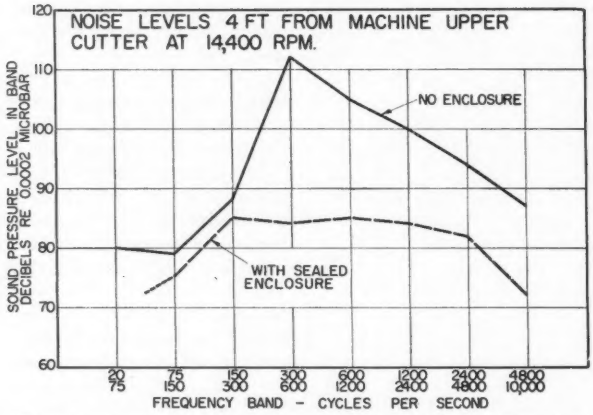

FIGURE 3. Noise levels measured near experimental machine with and without special enclosure over cutter head.

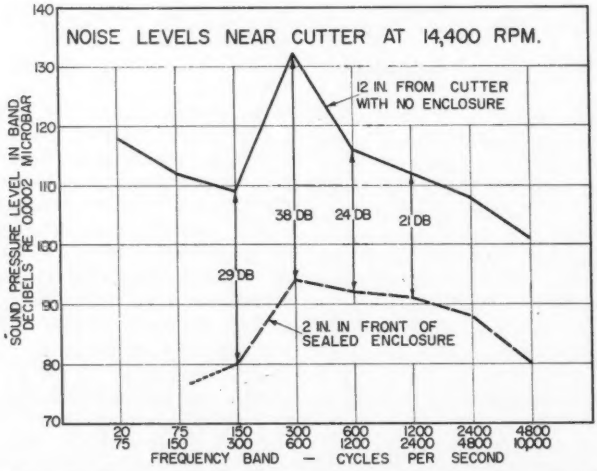

FIGURE 4. Noise levels measured near cutter head with and without special enclosure.

duction for noise passing out the exhaust line. An air intake muffler has been designed to provide about the same reduction for noise escaping through the air intake duct.

The noise levels measured quite near the cutter head are shown in Figure 4. The upper solid curve gives the noise levels measured 12 inches from the cutter with no enclosure. Notice that at the peak the noise levels are higher than 130 db for this close-in position. The lower dashed curve shows the noise levels at approximately the same location with the sealed enclosure in place. It is seen that the enclosure provides a 38 db noise reduction at the peak frequency for the close-in position.

The encouraging results on the cutter head have led to some preliminary noise control designs for quieting of the drive motors which can now be heard, almost for the first time. Also, the findings of this somewhat experimental noise reduction study are beginning to be applied to some of the larger moulding and planing machines.

The really important result of the study, however, is that it appears reasonable to anticipate that noise levels due to this type of wood processing equipment can be brought down to the range of "safe" noise levels for long-time hearing preservation.

Pneumatic Hammer on Plate with Resilient Support

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Bureau of Industrial Hygiene, Connecticut State Department of Health

THE B. F. Goodrich Company operates a Sponge Products Division at Shelton, Connecticut. One type of product made at this plant is cushioning material for mattresses, pillows, and furniture. An example of this type of material is shown in Figure 1. As you will observe, one side of this material has a great many geometrically arranged cylindrical cavities. The mold for this side must have corresponding cylindrical pieces attached to a flat plate, and attachment of these pieces during manufacture of the molds is a very noisy operation.

The cylindrical pieces are drawn shapes having a spherical end and range from about one-half to one inch in diameter and two to four inches in length. They are attached to the plate by "staking". As may be seen from Figure 2, a shallow circular groove is cut in the plate where each hollow pin is to be located and a pin is placed in the groove and tapped lightly to seat it. Each pin is secured by the use of a hollow cylindrical peening tool driven by a pneumatic hammer as shown in Figure 2. This operation swedges the aluminum plate metal to close the groove tightly about the pin. Obviously, a great deal of noise is produced by this operation.

The mold plate may be as large as three feet by ten feet and it is worked on in a horizontal position, supported by a very substantial low steel table. On its own initiative, in an effort to reduce the noise from the operation, industry had placed a "sandwich" of sponge rubber between two sheets of plywood on the table beneath the plate. It was said that this had reduced the noise considerably. However, the noise was still objectionable and it was desired that the hearing hazard potential be appraised. Accordingly, the Bureau of Industrial Hygiene of the Connecticut State Department of Health was requested to provide assistance in the matter. An octave-band analysis of the noise at the hearing level of the operator was made to determine the exposure under existing conditions. The second figure indicates the position of the worker with relation to the noise-producing tool.

In order to bring about additional noise reduction, the writer suggested installing a sheet of sponge rubber between the plywood and the plate. This was done so that progressing upward from the bottom, the arrangement consisted of a steel rail support, plywood layer, rubber layer, plywood layer, an old rubber layer, a new layer of sponge rubber and then the mold itself. The new top layer of sponge rubber was installed recently. Octave-band sound pressure levels were measured under conditions comparable to those mentioned above to determine the efficiency of the sponge rubber layer between the plywood and mold.

Figure 3 shows the overall and octave-band sound pressure levels before and after the change was made. The heavy line extending downward from 110 decibels to 95 decibels is, of course, the damage-risk criterion which we employ. It will be noted that, prior to installing the additional sheet of rubber, the octave-band sound pressure levels were well in excess of the criterion whereas they were only very slightly in

FIGURE 1

FIGURE 2

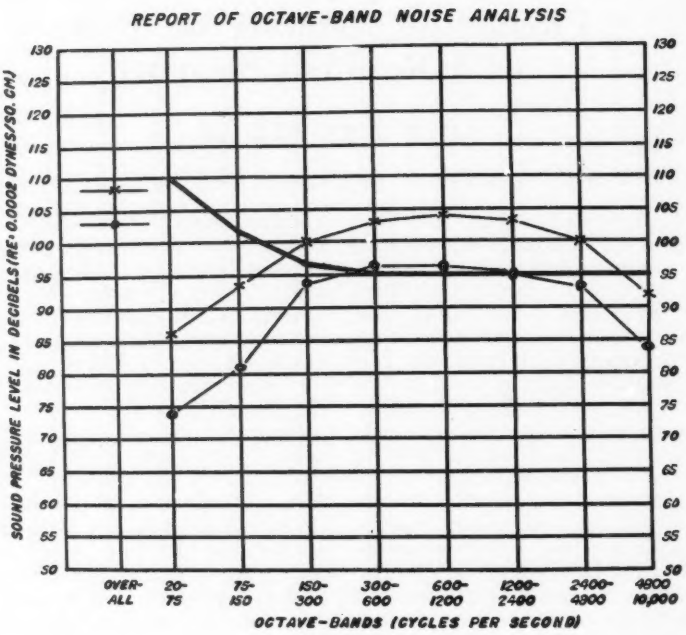

FIGURE 3

excess afterwards. In the upper six octave-bands, reductions of 6 to 8 decibels were noted while in the bottom two octave-bands, reductions of about 12 decibels were observed.

The noise reduction measure which has been described has proved entirely satisfactory and practical and has been in regular use for about two and one-half years.

A Muffler for Wet Hot-Acid Gases

VAUGHN H. HILL

E. I. du Pont de Nemours and Company

WITH the broadening use of chemicals in industry today and the development of new chemicals, corrosion continues to be an increasingly difficult problem, that extends even into the field of acoustics. On the other hand, new materials with superior chemical resistance continue to be developed, some of which have important possibilities in noise control.

The problem in this case was to provide a muffler for an excessively noisy industrial exhauster or blower handling a highly corrosive gas mixture at elevated temperature. The noise was a nuisance to both the plant and neighborhood. This particular blower operates at 1800 rpm and delivers 40,000 cfm against a static pressure of 48 inches of water. It is located inside a building but segregated from operating personnel so that the noise problem involves only that emerging from the stack. Figure 1 shows the general arrangement of the equipment. The blower pulls air through an oil-fired dryer and orifice scrubber and discharges it into a stack which extends about 100 feet above the fan discharge. The blower has a five-foot diameter impeller with twelve flat blades which are inclined slightly backward with respect to the direction or rotation.

Several conditions of this operation made the design of a muffler unusually difficult: (1) The gas being handled was so corrosive that stand-

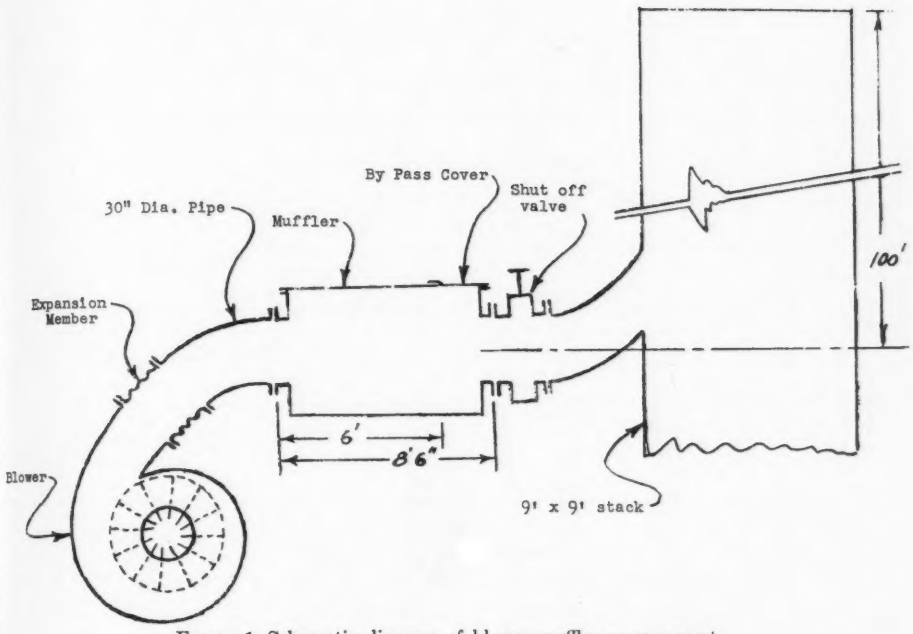

FIGURE 1. Schematic diagram of blower-muffler arrangement.

ard materials used in the manufacture of mufflers could not be used. In fact, commercial muffler suppliers would not bid on this application. (2) The gas was saturated with water which meant that the sound absorbing material used would have to function when wet. (3) The temperature of the gas was about 80°C which eliminated some of the more common materials such as polyvinyl chloride. (4) The space available was limited so that standard size mufflers could not be used. The allowable space for the muffler was 8½ feet (maximum). The effective length is only six feet however, when operating on by-pass. (5) The allowable air flow pressure drop through the muffler was two inches of water maximum. This meant that a complicated flow pattern could not be used.

The gas flowing through this system is essentially saturated air plus one part in 2000 sulphuric acid and various amounts of sulphur dioxide, oxygen, nitrogen and carbon monoxide which are the normal products of combustion of an oil burner. This combination of materials has proven to be excessively corrosive. In fact, du Pont corrosion consultants who are familiar with this process indicated that only Hastelloy C, rubber and Orlon* would stand such an atmosphere.

*Orlon is duPont's registered trademark for its acrylic fiber.

Figure 2 shows the octave band sound pressure levels created by this blower as measured one foot above the stack. Note the peak in the 300 to 600 cycles per second band caused by the fan fundamental. The fundamental frequency is the rpm multiplied by number of blades divided by 60. In this case it was 360 cycles per second. The noise is created at the cut off plate which is where the impeller tips come closest to the scroll. The impeller blades release their load at the cut off plate and the greatest turbulence takes place at this point.

Based on the peak noise level shown in this figure, it was decided that a reduction of 20 decibels at 360 cycles per second for the six-foot section of the muffler would be adequate to satisfy the neighborhood and working environment criteria.

Of the three materials suggested by the corrosion consultants; namely, Hastelloy C, rubber and Orlon, Orlon appeared to be the best material to use for absorbing sound. Tests were made of various denier, density and thickness packs. The best performance at 360 cycles per second was produced by a structure such as shown in section in Figure 3. It consists of a 3/16-inch thick perforated facing having 5/32-inch holes on ½-inch centers. This facing is a polyester resin reinforced with Orlon. In contact with

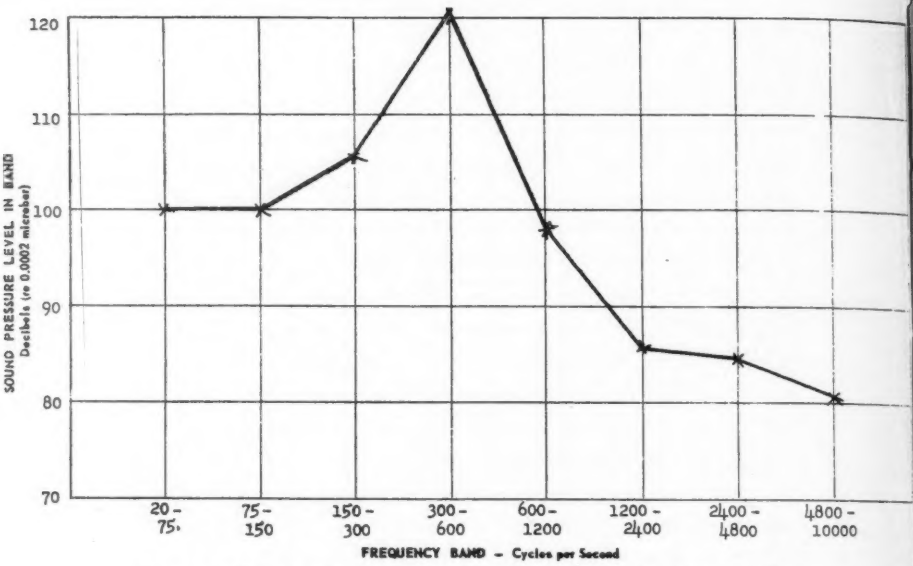

FIGURE 2. Noise level at one foot above discharge stack without muffler.

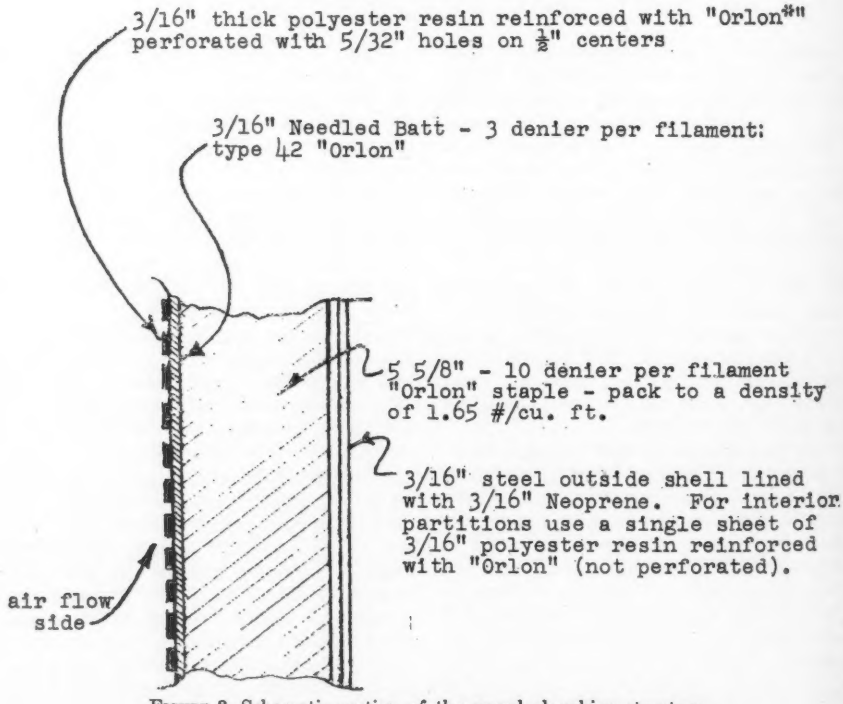
3/16" thick polyester resin reinforced with "Orlon*" perforated with 5/32" holes on ½" centers
3/16" Needled Batt - 3 denier per filament; type 42 "Orlon"
5 5/8" - 10 denier per filament "Orlon" staple - pack to a density of 1.65 #/cu. ft.
3/16" steel outside shell lined with 3/16" Neoprene. For interior partitions use a single sheet of 3/16" polyester resin reinforced with "Orlon" (not perforated).
air flow side

FIGURE 3. Schematic section of the sound absorbing structure.

the perforated facing is a $\frac{3}{16}$-inch thick needled batt of three denier per filament type 42 Orlon. Behind the needled batt is $5\frac{5}{8}$-inch of ten denier per filament staple of Orlon packed to a density of 1.65 pounds per cubic foot.

The needled batt, a felt-like material, is placed in contact with the perforated sheet to protect against erosion since the gas velocity through the muffler is in the order of 6700 feet per minute. It is to be pointed out, however, that

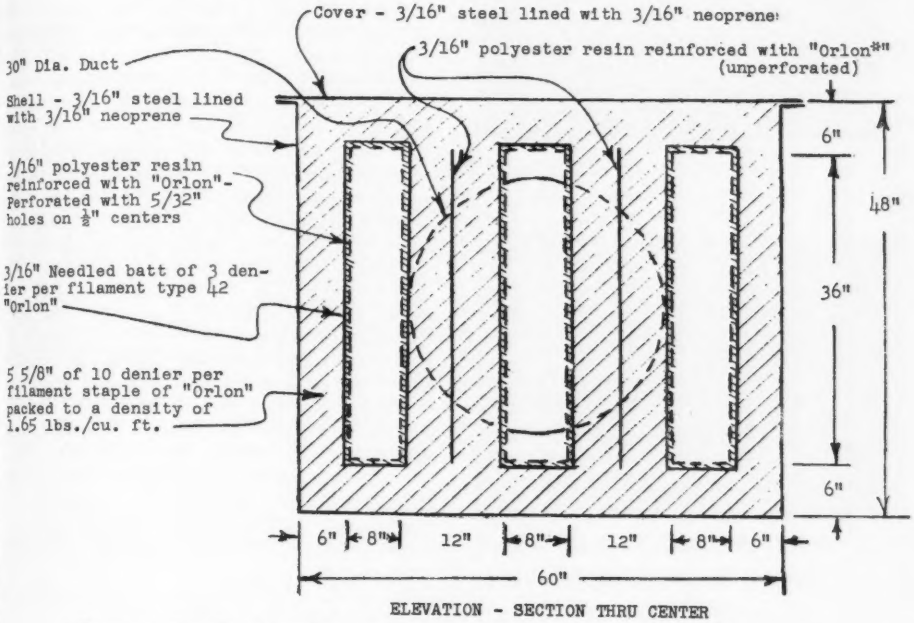
Cover - 3/16" steel lined with 3/16" neoprene
3/16" polyester resin reinforced with "Orlon*" (unperforated)
30" Dia. Duct
Shell - 3/16" steel lined with 3/16" neoprene
3/16" polyester resin reinforced with "Orlon"- Perforated with 5/32" holes on ½" centers
3/16" Needled batt of 3 denier per filament type 42 "Orlon"
5 5/8" of 10 denier per filament staple of "Orlon" packed to a density of 1.65 lbs./cu. ft.
6"
48"
36"
6"
6" 8" 12" 8" 12" 8" 6"
60"
ELEVATION - SECTION THRU CENTER

FIGURE 4. Details of muffler construction. (Elevation, section through center).

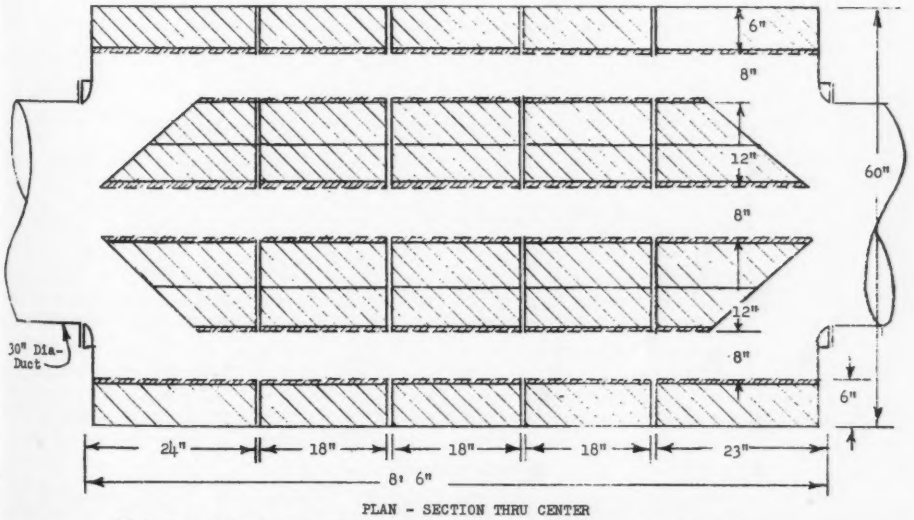

FIGURE 5. Details of muffler construction. (Plan, section through center).

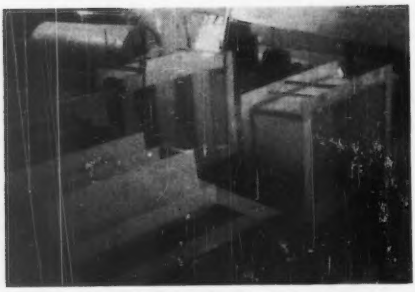

FIGURE 6. Interior muffler sections during construction.

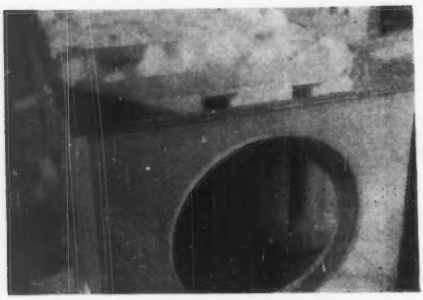

FIGURE 7. Muffler partially assembled.

three-inch long fibers of Orlon provide good binding properties when held in place by packing to a density of 1.65 pounds per cubic foot. It is possible that the staple pack would not erode even without the use of a needled batt. In addition, the chemical resistance and flexural strength of Orlon is expected to provide a more erosion resistant batt than one of short brittle glass fibers.

The performance of this structure, as measured in an impedance tube, is not appreciably reduced when the Orlon is wet. The Orlon fibers were dipped in water then tested as quickly as possible. Since Orlon is not wettable, the moisture drains off immediately. The absorption coefficient at 360 cycles per second is high.

In the design of a dissipative type muffler it is important to expose as much of the gas stream as possible to the absorbing surface. For this reason the muffler was designed with three narrow passages as shown in section by Figure 4. We are looking horizontally through the muffler in the direction of air flow. The muffler is rectangular in cross section and the duct from the muffler to the stack is circular. Note that each air passage is 8 inches wide by 36 inches high.

Figure 5 is a plan section of the muffler showing the cell type structure. The interior of the muffler was made up of five sections for easy assembly or removal for inspection. Another

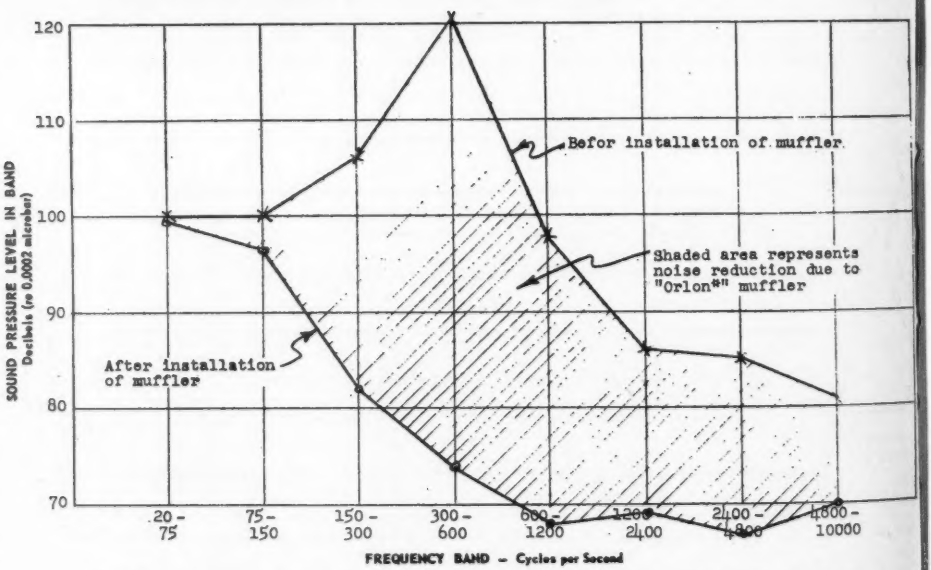

FIGURE 8. Comparison of noise levels one foot above discharge stack before and after installation of the muffler.

factor in sizing the sections was the fact that at present the pressure molded polyester resin sheets reinforced with Orlon are available in a maximum size of 4 feet by 3 feet. When larger sheets are available muffler construction can be simplified particularly where more space is available for the muffler than in this case.

Figure 6 shows three sections during construction. The polyester resin sheets reinforced with Orlon are cemented together with epoxy cement.

Figure 7 shows the muffler partially assembled. Each section is packed with Orlon before being placed in the shell. The shell is constructed of $\frac{1}{16}$-inch steel lined with $\frac{3}{16}$-inch neoprene. The cover is removable. One end of the cover is removable for by-pass operation when the stack is being inspected or repaired.

Figure 8 shows the performance of the muffler, the area between the curves representing the noise reduction. You will note the peak at the 300–600 cps band has been eliminated; in fact, the 360 cycle tone was not audible above the background noise after the muffler was installed. After 400 hours operation the muffler was inspected and it was in good condition with no significant signs of corrosion or erosion.

From a cost standpoint it might be expected that a material with such good chemical resistance would be expensive. When compared on the basis of densities used in mufflers, staple of 10 denier per filament Orlon is competitive with hairfelt and glass fibers and is only about three per cent of the cost of stainless steel or monel wool.

We have discussed a specific corrosive condition which was solved by using Orlon. You might have a different condition that could be solved to better advantage by using Dacron or nylon. They can function similarly. Each problem should be considered on the basis of the chemical resistance and temperature required. The scope of this paper could not possibly cover all of the questions you might ask about the chemical resistance or acoustical performance of these synthetic fibers. For any additional information you might need, it is suggested that you inquire of the Industrial Merchandising Division, Textile Fibers Department, E. I. du Pont de Nemours and Company, Wilmington 98, Delaware.

Pneumatic Sample Crusher Enclosure and Air Exhaust Mufflers

JAMES H. BOTSFORD

Bethlehem Steel Company, Bethlehem, Pennsylvania

TWO PNEUMATIC crushers are used for pulverizing samples of stone, ore, slag, refractory materials, high-carbon irons and steels preparatory to chemical analysis. Each of the crushers shown in Figure 1 consists of a hardened steel mortar and pestle operated by an air hammer such as might be used in riveting. Approximately one hour of actual crushing time is distributed between the two machines per work shift. The overall noise level at the crusher operator was in excess of tentative criteria, whether one or both crushers were operating.

The noise from the crusher is generated partly by hammer exhaust but principally by the vibration of the sample holder and machine parts which results from the hammer impacts. Noticeable noise reduction was obtained by placing a rubber pad beneath the mortar but a total enclosure was necessary to provide the noise reduction desired.

The sound attenuating enclosures shown in Figure 2 were constructed for noise reduction. Your attention is called to the following features:

(1) *Wall construction to provide desired transmission loss.* From a knowledge of the octave-band noise levels at the crusher when operating, a wall construction capable of providing the desired noise reduction was selected from tables of sound-transmission loss. A margin of safety was allowed since the transmission loss obtained in the field often falls below that measured in the laboratory. The construction selected was ¼-inch plywood over a 2 x 2 inch frame.

(2) *Sound-absorbing lining.* Glass fiber blanket 2 inch thick was selected for lining the interior since this material has high sound absorption throughout the frequency range to be attenuated.

(3) *Enclosure isolated from crusher.* Mechani-

FIGURE 1. Pneumatic sample crushers before noise control measures.

cal ties between the enclosure and the crusher were limited to that through the floor.

(4) *Refrigerator hardware and gaskets on access door.* The door through which the sample is placed in the crusher is of the same construction as the wall. Air-tight closure is assured through use of refrigerator hardware and gaskets. The window is of double-strength glass which has a sound transmission loss comparable to that of the walls. The glass was bound with friction tape at the edges prior to glazing to improve sound-transmission loss. The principal function of the tape is to damp mechanical resonances of the pane and, thereby, prevent relatively free transmission of sound through the window at the frequencies of pane resonances. Use of the tape also prevents sound leaks at the edges of the pane by assuring air-tight glazing.

(5) *Openings kept to minimum size or treated.* Crusher controls consisting of an air valve for the hammer and a foot pedal for pressing the hammer against the pestle were brought outside the enclosure. Openings for these were kept as small as possible. The crack at the floor was sealed with felt. To permit escape of air exhausted from the hammer, a duct lined with a 2-inch thickness of glass fiber was provided at one corner of the enclosure. The duct extends from the floor to the top of the enclosure, is 4 x 4 inches in cross section and contains two 90° bends. Attenuation of sound through this duct was calculated to be approximately equivalent to that through the walls except at low frequencies.

A close-up of the enclosed crusher with the door open is shown in Figure 3. The door gasket and glass fiber lining are visible; the exhaust duct constructed of 1- x 8-inch boards may be seen in the right rear corner of the cabinet. Installation of these enclosures reduced the overall noise level at the crusher operator by 15 db, to safe levels.

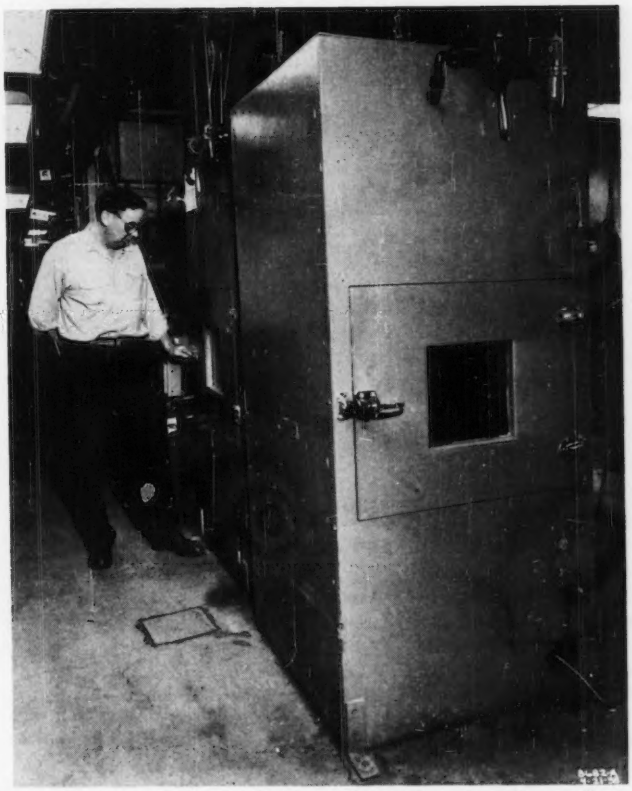

FIGURE 2. Enclosures for control of noise from two pneumatic sample crushers.

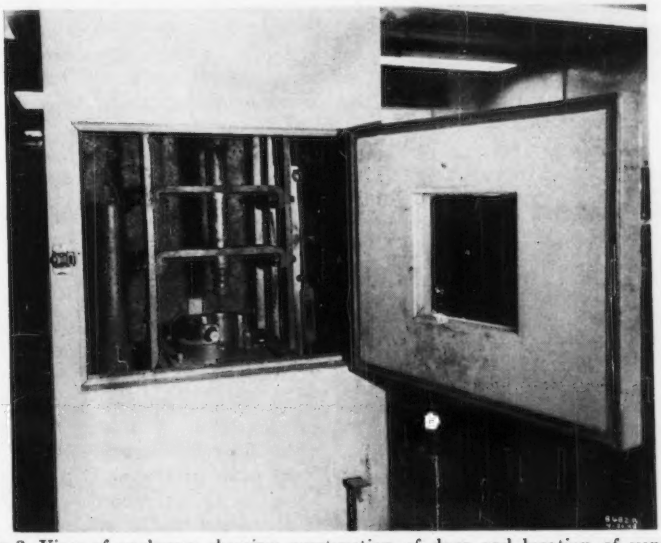

FIGURE 3. View of enclosure showing construction of door and location of vent duct.

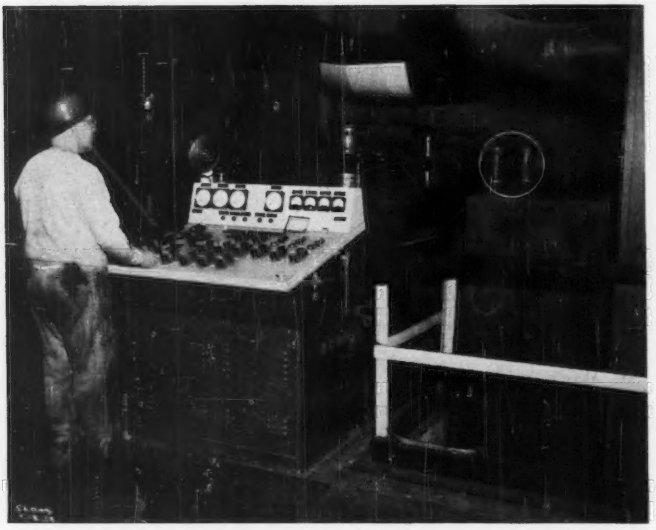

FIGURE 4. Muffler on exhaust air valves in pipe mill.

A new electric-weld pipe mill presented a severe noise problem. Numerous air cylinders are used throughout the mill to actuate the pipe manufacturing and handling machinery. With the mill operating, exhaust of air from the many cylinders produced high noise levels almost continuously. Some of the cylinder exhausts were throttled through orifices to control operation so that the noises from these exhausts were prolonged.

Approximately 150 exhaust mufflers of a type commercially available were installed. Two of the mufflers are shown behind the machinery in Figure 4. These mufflers distribute the flow of exhaust air over a large area and eliminate the high velocity responsible for the noise. The muffler is available in several sizes, one for each standard pipe size up to 2 inches, and is provided with male threads for direct attachment. When the proper size muffler is used, air flow is reduced only by 3%.

Where throttling of an exhaust was necessary, the orifice formerly used was replaced with a suitable reducer and muffler of nominal size most nearly equal to the orifice diameter. Where further reduction of exhaust rate was necessary, a short length of pipe was interposed. After installation of the mufflers described, air exhaust noise was well within safe levels, being inaudible above shop background noise.

The Good and Bad of Acoustic Treatment

LYLE F. YERGES

Introduction

CONTROL OF noise at the source. The best idea yet developed in acoustical design is to avoid making noise. It's always the most effective, and it's usually the cheapest.

Medical control of hearing losses. It would appear that protecting the individual against noise would be the next best method. However, you've all had too many painful experiences trying to get workers to wear gloves, goggles, safety shoes and hats to need any reminder of how difficult it would be to get them to wear ear plugs or muffs. Furthermore, it is very difficult to forecast susceptibility to noise damage or to measure hearing loss accurately when it does occur. Even more frustrating is the fact that hearing losses can be determined only after the damage is done—and that is too late.

Noise control by acoustical treatment. To most people, acoustical treatment means the application of acoustical tile or absorbents to the ceiling of a room. This is the commonest form of noise control, and its use is widespread. Like the word "treatment", however, it suggests a cure or correction of an existing ill. Like most cures, it can be expensive and may not be completely satisfactory. For example, at the 100-plus db level of many factories, it is very difficult to remove even five decibels by absorption, whereas a simple process change or re-design of a machine could reduce the level by ten or more decibels.

In those cases where the problem is to prevent passage of noise through walls, acoustical absorption is virtually useless, and the so-called "treatment" isn't really a treatment after all.

It is apparent, then, that a few definitions are in order. "Acoustical treatment" refers to the use of materials, constructions, systems, or combinations or all three to: (1) absorb sound, (2) isolate noise sources, (3) insulate rooms from sounds produced elsewhere, and (4) prevent passage of sound out of a building to the surrounding neighborhood.

Sound Absorbents

Sound absorbents are materials which absorb acoustic energy and convert it to a different form of energy, usually heat. Acoustical tile is a common form of acoustical absorbent. Hanging baffles, functional absorbers, mineral or glass wool batts or blankets, panels covered with or containing absorptive materials are also types of acoustical absorbents.

The principal use for absorbents is to prevent or reduce reflection of acoustic energy which strikes them. This prevents reverberation of the noise sources. Obviously, absorbents can't reduce the level of the sources. A noise generator, such as a noisy machine, will continue to put out just as much noise whether these absorbents are in the room or not. However, in a reverberant space, the noise level is usually far higher than the noisiest machine; that is the condition which absorbents can correct.

As their name implies, absorbents "absorb" or "soak up" sound. Like a blotter, however, they don't prevent passage of noise through them.

If you are closer to the noisy machine than to acoustical absorption, you'll notice very little, if

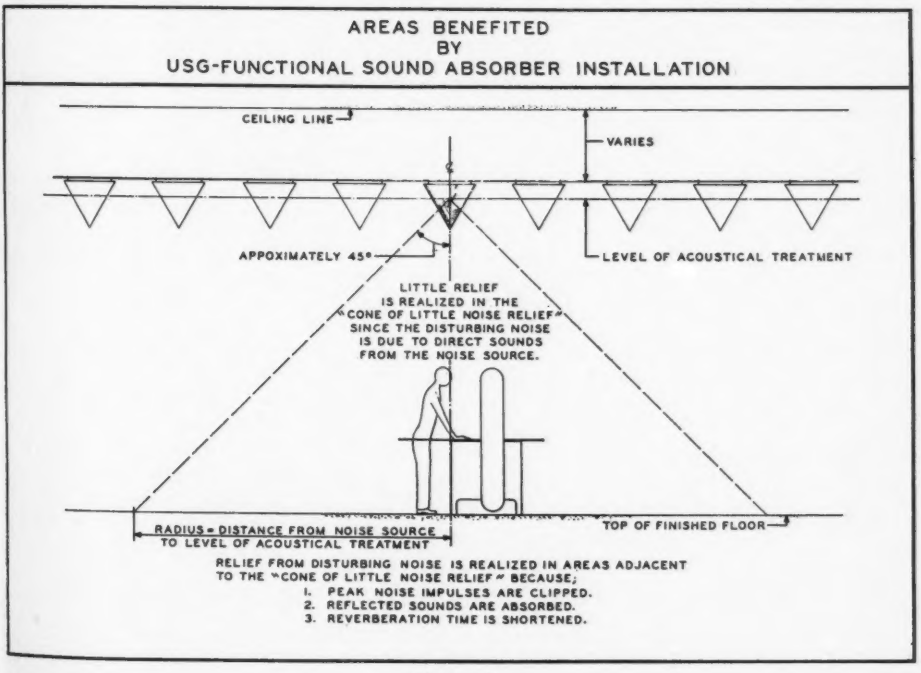
AREAS BENEFITED
BY
USG-FUNCTIONAL SOUND ABSORBER INSTALLATION
CEILING LINE
VARIES
APPOXIMATELY 45°
LEVEL OF ACOUSTICAL TREATMENT
LITTLE RELIEF
IS REALIZED IN THE
"CONE OF LITTLE NOISE RELIEF"
SINCE THE DISTURBING NOISE
IS DUE TO DIRECT SOUNDS
FROM THE NOISE SOURCE.
RADIUS = DISTANCE FROM NOISE SOURCE
TO LEVEL OF ACOUSTICAL TREATMENT
TOP OF FINISHED FLOOR
RELIEF FROM DISTURBING NOISE IS REALIZED IN AREAS ADJACENT
TO THE "CONE OF LITTLE NOISE RELIEF" BECAUSE;
1. PEAK NOISE IMPULSES ARE CLIPPED.
2. REFLECTED SOUNDS ARE ABSORBED.
3. REVERBERATION TIME IS SHORTENED.

FIGURE 1

TABLE I

Decibel Level	Relative Energy	Difference
105	31,630,000,000	
		6,510,000,000
104	25,120,000,000	
		5,170,000,000
103	19,950,000,000	
		4,100,000,000
102	15,850,000,000	
		3,260,000,000
101	12,590,000,000	
		2,590,000,000
100	10,000,000,000	
		2,057,000,000
99	7,943,000,000	
		1,623,000,000
98	6,310,000,000	
		1,298,000,000
97	5,012,000,000	
		1,031,000,000
96	3,981,000,000	
		818,000,000
95	3,163,000,000	
		651,000,000
94	2,512,000,000	
		517,000,000
93	1,995,000,000	
		410,000,000
92	1,585,000,000	
		326,000,000
91	1,259,000,000	
		259,000,000
90	1,000,000,000	

any, reduction in noise level. The *direct* sound from the machine reaches you before the reflected sound, so you'll get its full effect. In the conical volume shown in Figure 1, there is little noise relief. The volume is a right angle cone with a base whose radius equals the ceiling height of the room. Anywhere in that cone, the noise level is not appreciably reduced by using absorbents on the ceiling. The volume of the cone can be reduced by lowering the ceiling or dropping the absorbents down nearer to the machine. However, even within the cone these results are accomplished: (1) sounds become directional and identifiable, since they are not lost in a sea of confused, reverberant, reflected sounds, (2) communication becomes easier, and (3) peak impulses are clipped and the sharp "sting" is taken out of the sound.

In offices or locations where noise levels are under 80 decibels, the reduction accomplished by absorption is usually appreciable and appreciated. In areas of 100 decibels or more, the effect is rarely enough to solve the problem and the end results may be disappointing, even though the condition is very much improved. Here's what it looks like in numbers.

At 105 decibels, the relative energy is over thirty *billion* units. To drop down one single decibel is to remove over six-billion units. In other words, the difference in level between 104 decibels and 105 decibels is more than all the energy at 98 decibels. And believe me, 98 decibels is noisy. So we can do a remarkable job in soaking up energy with absorbents, but still end up with a noisy room. (See Table I.) That's the trouble with humans; they react logarithmically to stimuli instead of in a sensible, straight-line manner.

Isolation

The actual acoustic energy being emitted by the machine is probably quite small. However, it may be setting other large surfaces into vibration, and they may be radiating far more energy than the machine itself.

Check these points:

1. Are there any large metal panels or covers which are vibrating? If so, either damp the vibrations with damping materials such as special mastics or resilient pads, or resiliently mount the panels.

2. Is the machine vibrating the whole floor or structure of the building? If so, install properly designed resilient mounts to isolate the machine from the structure. Forges and presses, for example, should be set on their own separate foundations not connected to the building floor or structure. Don't attempt to design any of these mounts yourself. You can make the situation worse. Call in the experts here. There are good, standard, commercially available mounts designed for small equipment. Others must be specially built.

3. Can you cover or enclose the entire noisy machine? A proper enclosure, consisting of heavy, rigid panels, lined on the inside with absorptive material, can kill a lot of the racket before it escapes into the rest of the room. Remember, though, the absorptive material alone, will not contain the sound. It absorbs sound contained by the panels. (Figure 2.)

4. Can you move the machine to another area where it will annoy fewer people? Or can you enclose the operator in an insulated space and protect him from the noise? The insulated space is essentially the same as the enclosure just described, only this time the panels keep the noise out and the absorption kills reflections within the enclosure.

The four solutions we've just discussed can reduce the direct sound coming from the machine by as much as 25 decibels.

Combination Solutions

Sometimes you can't completely enclose a machine without seriously interfering with an operation. However, you can usually put a partial

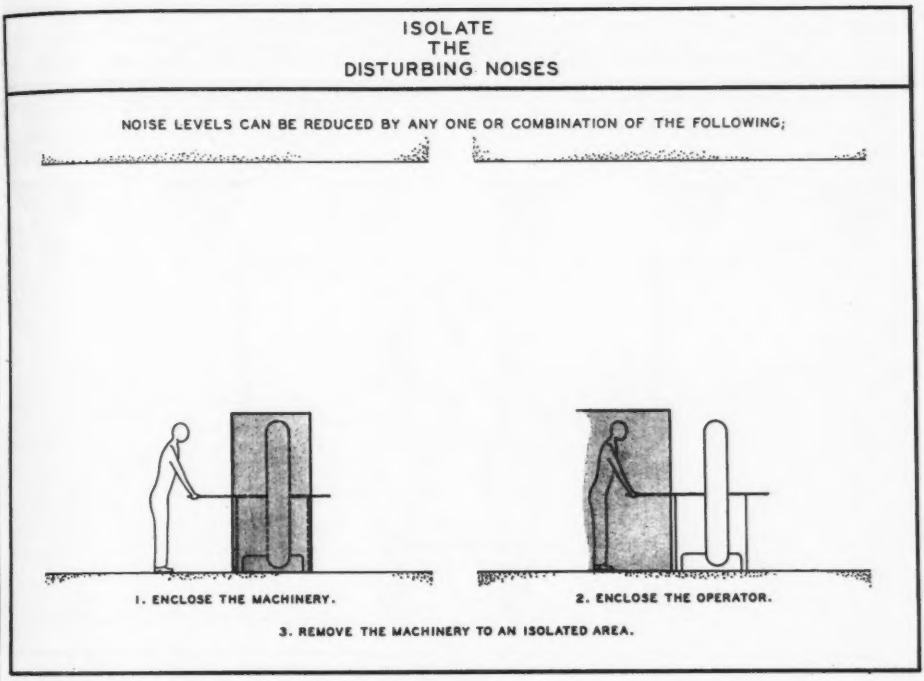
ISOLATE
THE
DISTURBING NOISES
NOISE LEVELS CAN BE REDUCED BY ANY ONE OR COMBINATION OF THE FOLLOWING;
1. ENCLOSE THE MACHINERY.
2. ENCLOSE THE OPERATOR.
3. REMOVE THE MACHINERY TO AN ISOLATED AREA.

FIGURE 2

enclosure around it. If so, heavy, rigid panels, lined on the inside with absorbents, will reduce the sound being radiated by the machine to the surrounding area. However, if the operator is within the enclosure, he won't get much benefit from the absorption, because the direct sound from the machine will still reach him first. However, his neighbors will be a lot happier.

If you can't put a ceiling on the enclosure, try to hang absorbents above it. (Figure 3.) Here the functional absorbers are handy gadgets. They let you load a lot of absorption into a small area. These partial enclosures, combined with absorbents, can provide up to 20 db relief.

From this, it would appear that isolation and insulation are far superior to absorption. If only a few machines are involved in the problem, or one individual machine is the particular offender, that is true. If, however, the whole room is filled with machines, all of them making noise, it is no longer so. A typical example is a weaving shed in a textile mill or a room full of automatic screw machines. All you can do there is to mount the machines resiliently, dampen any panel resonances, and use a lot of acoustical absorption through the area. Then, you'll still have to settle for a five decibel reduction or even less.

Insulation

One more major problem is keeping factory noises in the plant and out of the adjoining offices and neighborhood. That means sound insulating walls and surfaces. Again, let me remind you, acoustical absorbents do not prevent sound transmission through them. An absorbent is like a piece of Kleenex—it absorbs water, but water goes right through it.

It takes constructions, not materials, to prevent sound transmission. If you want to keep sound out of an office or within a plant, you must use heavy, rigid, absolutely tight walls. The best type would be twelve inches of heavy masonry, but that's often completely impractical. The next best bet is a wall whose surfaces are resiliently mounted to dissipate the sound energy in the springy mounts. Again, call in the experts here. They'll save you a lot of money.

The real hitch in these constructions is openings. An open window or door, or even a keyhole can vitiate the whole thing. In designing a plant or office within a plant, think seriously of win-

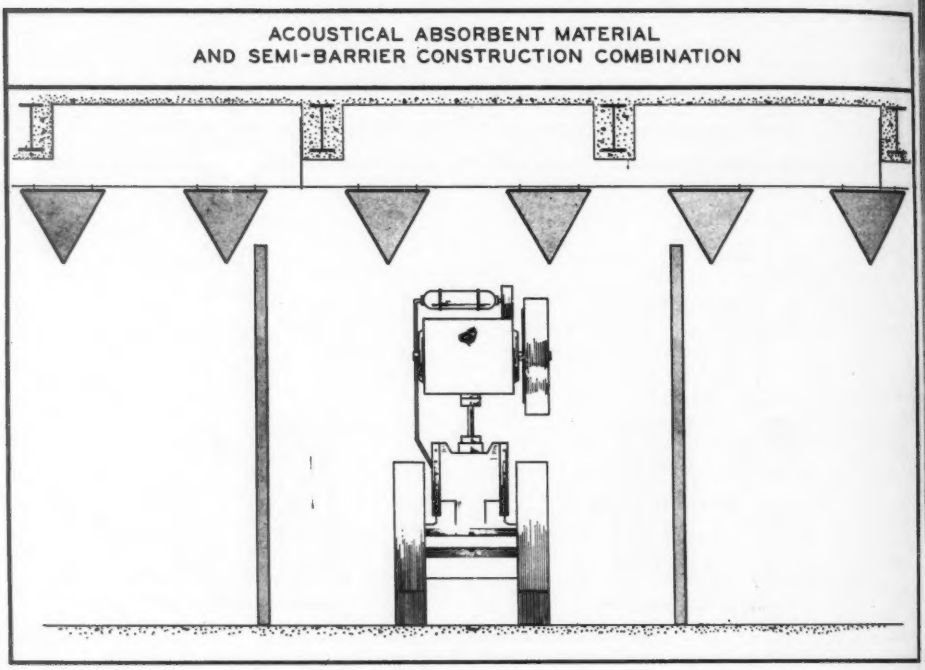

FIGURE 3

dowless walls, air-conditioning, and artificial light. Any opening lets the sound right through regardless of how good the wall may be.

Summary

First, determine "What is the problem?" and then determine the solution. This is the most frequently overlooked part of the whole job. For example, we've had people ask us to install an acoustical tile in their plant to quiet the noise of a rock crusher. Investigation showed that two men went into the noisy area twice a day for about fifteen minutes each time. We advised ear plugs. We have had people ask us to put tile on the walls of their plant because neighbors complained of the noise. We told them to close the windows.

When faced with a noise problem and before you make your decision, answer the following pertinent questions:

1. *What are you trying to do?*
   - Keep noise in the plant?
   - Keep noise out of the office?
   - Reduce noise levels in the plant?
   - Quiet a noisy machine?
   - Isolate a noisy operation?
2. *Whom are you trying to protect?*
   - The operator of the noisy machine?
   - The workers in the entire plant?
   - A single observer of a noisy operation?
   - A few noise-susceptible individuals?
3. *Why?*
   - Are you trying to avoid compensation claims?
   - Is there evidence of noise damage?
   - Is verbal communication impossible?
   - Are workers being distracted?
   - Are operators unable to identify necessary sounds from their own operation?
   - Are you trying to make a few neurotics happy?
   - Is everyone complaining?
   - Are the neighbors complaining?
4. *What are the alternatives?*
   - Can you move the noisy machine?
   - Can you protect the operator by putting him in an isolation booth?
   - Can you move the operator and his controls, dials, and equipment to a quiet place outside of the noise?
5. *Will the resultant improvement be enough to justify the expense?*
   - Will a 5 decibel drop do enough good? For

example, will reducing the level from 155 db to 110 db be enough?

6. *Should you consider an entirely new approach?*
   Can you use a different process?
   Would a new plant or a new location be the only practical approach?

In a few words: Identify your problem—THE DIAGNOSIS—then Decide on the proper solution to the problem—THE CURE—and finally, Choose the proper materials, constructions, systems, or plans—THE MEDICINE. Chances are the patient will recover, or at least feel a lot better.

Tumbling Barrel Noise Control

JAMES W. LAKE

DURING JUNE of 1954, one of our insureds in the foundry industry became interested in noise control for their cleaning room operation. We were called in to make a noise survey as a part of our periodic service to the foundry. From previous contacts, we knew that our first efforts would be directed toward tumbling barrel noise reduction. An octave band analysis of one tumbling barrel operating was made. The over-all noise level, at a distance of three feet, was 110 db. The ambient noise level, with all ten tumblers operating, averaged 112–114 db. The

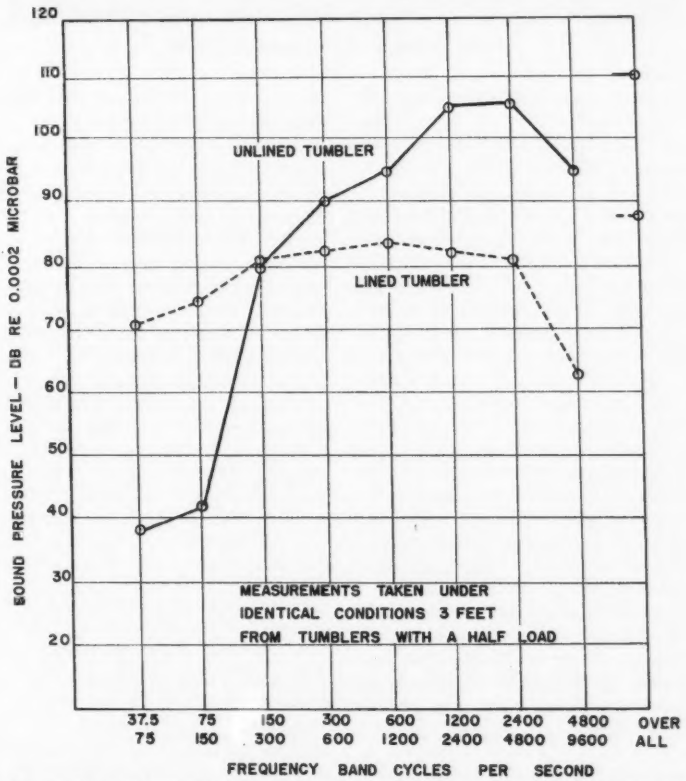

FIGURE 1. Comparison of octave band analyses of noise with unlined (solid line) and rubber-lined (dotted line) tumbling barrels.

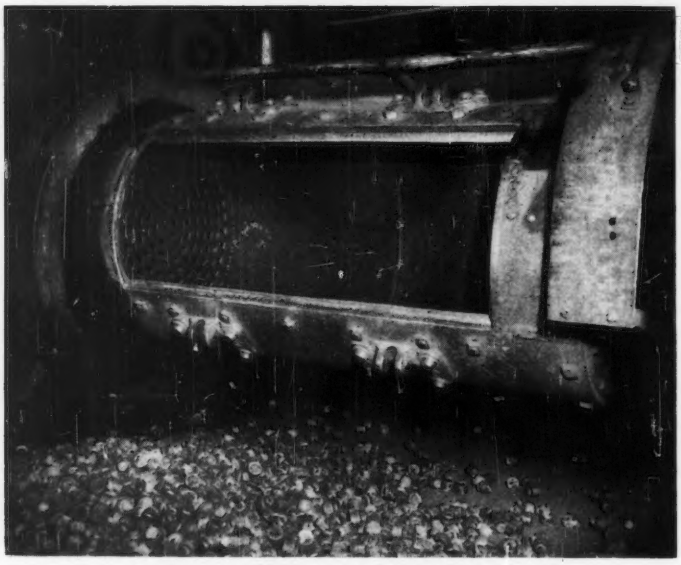

FIGURE 2. Rubber-lined tumbling barrel.

solid line in Figure 1 indicates the frequency distribution of such noise.

Management had a number of ideas concerning noise control. These included: (1) baffles around the tumblers, (2) treatment of the outside of the barrels with an undercoating material, (3) acoustical tile on the ceiling and walls, (4) enclosure of individual barrels, and (5) enclosure of the area. These methods were discussed singly and in combination. They were all eliminated for one or more of the following reasons: (1) the noise reduction would not be commensurate with the cost, (2) additional and excessive casting handling, (3) additional maintenance, and (4) poor material flow.

During 1955, a sales engineer stepped into the void with a steel-backed rubber lining. The insured called us and asked for our opinion. We encouraged them to install one on a trial basis and asked that we be informed when the installation was completed so that we could take comparative measurements.

In November, 1955, measurements were made of both a lined (Figure 2) and an unlined tumbler having identical size and identical loadings with identical castings. The lined tumbler noise octave band analysis showed the noise levels (Figure 1) to be below many criteria guide levels. The reduction is particularly noticeable in the higher frequencies. The noise levels remain below the presently accepted criteria guide established by the Subcommittee on Noise in Industry of the American Academy of Ophthalmology and Otolaryngology.

After a test period of approximately one year, during which the condition of the lining was watched closely, the remaining nine tumblers were lined. In November, 1956 an octave band analysis was made with nine lined tumblers operating with full loads. The analysis was made in the center of the tumbling area. The over-all sound level was 85 db as compared to 112 db for a previous measurement with ten unlined tumblers in operation.

The approximate total cost of the ten liner installation was $2,000. The sizes are tabulated, as shown:

Number of Tumblers	Tumbler Size in Inches	Liner Thickness in Inches	Material
1	36 × 72	¾	Resilient rubber with steel backing bolted to the inside of the tumbler.
1	36 × 60	¾	
8	24 × 48	½	

A check on these barrels in April, 1958 showed no lining wear. The actual over-all maintenance cost on the tumbling barrels has been reduced. The ventilation on the barrels was improved, probably because of the decrease in tumbler volume.

Many methods of tumbler noise reduction were considered. The method of tumbler lining was chosen and the resulting noise levels meet present-day criteria guides. The approximate

cost of $80 to $90 per decibel reduction was considered a good investment, particularly so since maintenance costs on the tumblers have decreased.

The casting cleaning and handling process was not hampered in any way by this treatment, and the ventilation of the tumbling barrels was improved. In general, there are other applications, such as hoppers, tumble and table blast machines, in some instances shakeouts, ball mills, etc., where this type material can be applied for noise reduction.

Community Noise Control by an Aircraft Manufacturer

ROLAND C. BERGH

Republic Aviation Corporation

REPUBLIC Aviation Corporation manufactures military aircraft for the United States Air Force and in conjunction with this operates an airport at Farmingdale, Long Island. Republic has been operating in this location for about twenty-five years. Business was principally of a military nature except for a short period when transport and private planes were manufactured.

During the Second World War, approximately 17,000 F47 Thunderbolts were made and noise created did not seem to concern anyone. The F47 was a propeller driven airplane with an internal combustion engine. After World War II the production of jet aircraft, the F84, was initiated and although many were manufactured and flown through the year 1953, there was no awareness that a serious community noise problem existed. However, early in 1954 Republic became conscious of an adverse growing community reaction to the operation. At this time, through no fault of Republic they were forced to run engines on the ground to check them out, and swing the radio compasses, which is quite complicated, and which required the actual running of the engine to meet military requirements. These engines were run at all hours of the day and night in order to get back on schedule.

At this time the writer was put on part-time status of Noise Coordinator, and had the Armour research foundation of Chicago make a noise survey and present a set of recommendations which they felt would provide acceptable noise levels for a plant situated in the vicinity of a community such as ours.

Immediately after this survey a noise complaint record procedure was instituted to permit pinpointing the most objectionable procedures and to inform individual complainants when we had taken constructive action on their complaints. It was found that by far the largest number of complaints resulted from ground running of the aircraft, not from flight.

Ground running consists of the initial running of the engine in the airplane and the various inspection procedures that the military require performed before first flight inspection. The compass has always been a mysterious thing. You have to turn the airplane around while checking it, and the specifications required running of the engine in order to do this.

It was found that the complaints received centered mostly about the operation of the compass test. Thus, the plant endeavored to find out if they could simulate the effect of the engine without actually running it and thereby eliminate this very large source of noise complaint. They were very successful in making this change in a period of about six weeks and thereafter didn't have to run the engine for this operation.

The company still had to run the engine to check out other systems that were attached to the engine. At that time they worked on their first experimental airplane muffler to take care of the remaining complaints associated with ground operations. During the calender year 1956 five of these airplane mufflers were placed into operation.

The final muffler design is shown in Figure 1. This muffler is covered with insulation and equipped with coupling sleeve at the front. This coupler provides a tight fit around the tail area of the plane and contributes greatly to the noise reduction attained. The simple addition of this coupler increased overall sound attenuation measured 250 feet away by 50%.

The use of these mufflers for all ground running during the year 1956 reduced complaints to less than half of those received in 1955. There

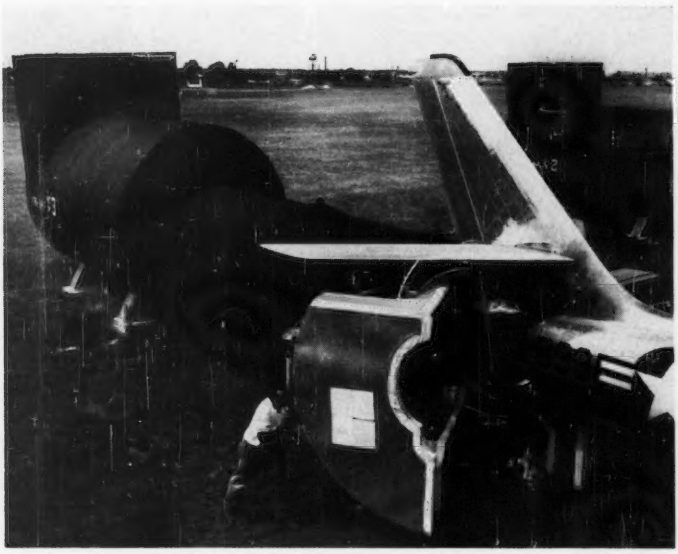

FIGURE 1. Airplane muffler being closed about the tail of a jet plane.

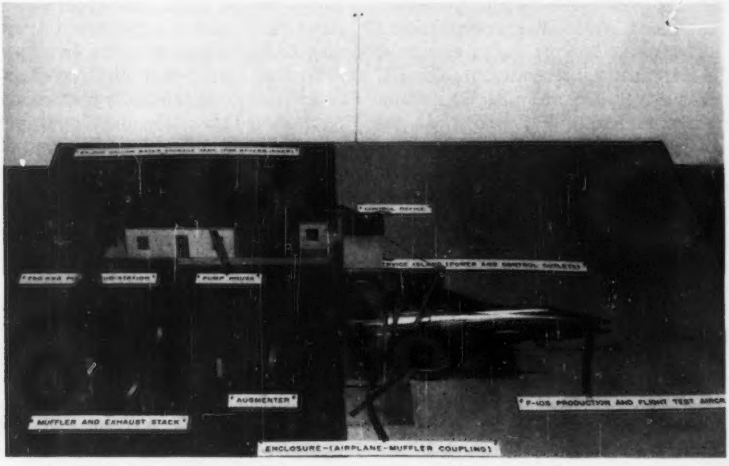

FIGURE 2. Model of muffler facility being constructed for ground running of the F105.

were practically no complaints during 1957 up to the time that this airplane phased out of production.

During 1957 the President of Republic appointed the author as his staff assistant to study the Noise Abatement Program full-time. It has been most beneficial to have the president stand behind me, and the department heads and the working personnel have gradually come to recognize the importance of jet engine noise control without appreciably increasing manhour requirements.

Republic is now in production on a supersonic fighter bomber, the F105. Although delivery is scheduled for this particular aircraft at a considerably lower rate than for the F84 the noise caused by the use of the afterburner creates a much more severe noise but of a shorter duration. Noise abatement facilities equivalent in function to those shown in the Figure 1 are now

being installed and will be in operation during the summer of 1958. The cost of an airplane muffler of this new type capable of absorbing the energy of this much more powerful engine is roughly ten times the cost of the older unit.

Figure 2 shows a model of the facility now being built for the F105 airplane. On the right is the aircraft itself, and to the left is a section for the purpose of illustrating how the rear of the aircraft is coupled to the front end of what is called an augmenter. To the left of that round pipe is the coupler itself.

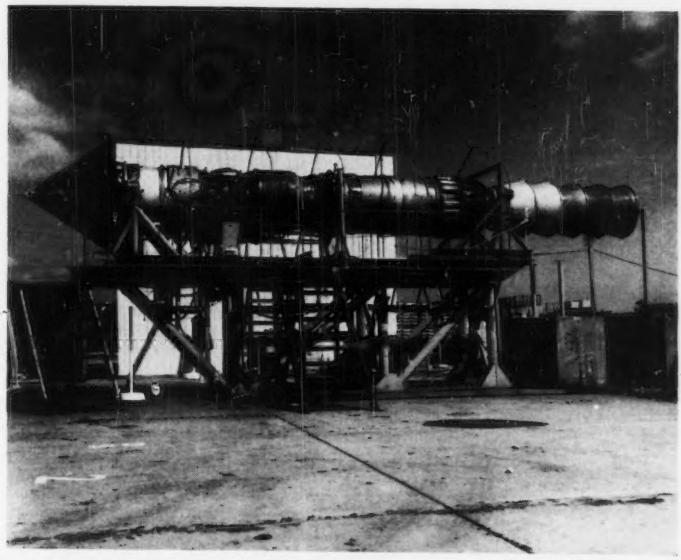

FIGURE 3. Engine test stand with conical frequency shift attenuators on right.

FIGURE 4. Use of ear protectors with receiver and microphone for communication during tests.

Figure 3 is a picture of a test stand where the engine is checked out, which must be done occasionally. Directly behind it on the right are a series of conical sections. This attenuating device works principally on the frequency shift principle. Exhaust gas is forced through millions of small holes in the conical sections. These sections are made entirely out of stainless steel. This unit is being developed at the present time for possible use with the complete F105 airplane.

Personal hearing protection devices are needed in areas around and in the airplane during various test periods. Muff types are regularly used for all concerned personnel. These muff types have been equipped with hearing receivers. In addition, microphones are supplied which operate only when the button on the microphone is squeezed. By holding this microphone up to his lips a man can talk clearly in an ambient noise level of 130 decibels. Without this button type microphone communication would be destroyed due to the ambient noise level.

In Figure 4 three people are shown talking to each other. One to the front, one to the side and one in the cockpit. When the engine is running at full power the personnel under the plane would be away from this area. At such a time, these three men can communicate successfully without loss of hearing due to the high noise levels.

In summary, experience in testing jet-type planes indicates that:

1. Ground engine runs must be carefully controlled and engine time adjusted to a minimum. Written official procedures are in effect and are issued after careful review with production personnel.
2. Ground mufflers for engine and aircraft are mandatory.
3. Community noise complaints must be carefully investigated and the complainer given the satisfaction of a reply.
4. Public Relations Department must continuously keep the community informed on our operations through the local press and otherwise.
5. Take-off and landings are not a normal cause of adverse community reaction providing pilots follow standard flight patterns.
6. Occasionally, adverse weather may accentuate ground and flight noises.
7. Personal hearing protective devices are required during certain engine running operations.

Noise Specifications

VAUGHN H. HILL

E. I. du Pont de Nemours and Company

THE FIRST approach to noise control in many plant programs is the correction of existing noise problems. It soon becomes apparent, however, that a preventative program is necessary to stop the accumulation of new noise problems which are created when building new plants, modernizing old ones, or replacing old equipment. Noise characteristics of equipment must be known to carry on a successful preventative program.

It has been found that noise specifications can be a great help in securing such information. Noise specifications define maximum acceptable noise levels for equipment to be used in specific installations. They also prescribe instrumentation, environment and procedures for measuring the noise produced by the equipment. They are specifically intended to be used in the purchase of equipment.

Noise specifications based on over-all sound pressure levels are adequate for general industrial use. Specifications should be based on octave band analyses so that the relation to criteria and performance of control measures can be determined.

Specifications based on sound power output would of course be the ultimate goal. However, few manufacturers can supply such data. This leaves but one alternative and that is to specify noise performance of equipment based on octave band sound pressure levels measured under specific conditions. To do this in such a way that vendors can easily comply, a specification such as the one to be discussed here can be used.

The *Noise Specification* contains information under the following headings:

1. *General*—This defines the objective of the specification.

2. *Instruments*—Describes different types of instruments and their calibration.

3. *Noise Tests*—Describes test room, effect of environment and locations for test readings.

4. *Records*—Covers recording of data and communication with manufacturer; refers to figures which show suggested form for test data.

5. *Sound Level Specifications*—Describes criteria and refers to table which states criteria for different types of environment in which the equipment is to be located.

6. *Special Requirements*—Unusual conditions.

By specifying maximum noise levels such as suggested in this specification vendors will be placed on a more equitable basis for bidding and will soon recognize the importance of designing equipment that is not excessively noisy. It will also help to eliminate unreasonable purchaser demands if considerable additional cost is involved. In many cases, the machinery manufacturer is in the best position to reduce the noise of the machine at its source with built-in designs. It is expected that many such designs will not materially increase the cost of the machine.

All plans for new equipment should be checked. Where it appears that noise will exceed the criteria for the particular environment, noise specifications should be used. It is often more economical to correct noise problems in the design stage than after the equipment has been installed.

To assist personnel in anticipating possible noise problems it would be helpful to provide a list of the noise levels produced by equipment used in your plants. This can be done by actual measurement, by calculation, or by reference to data such as compiled by Armour Research Foundation and published in the American Industrial Hygiene Association Quarterly of December 1953.

Summary of the Fourth Noise Conference of the Associated Industries of New York State

FRANK PATTY

General Motors Corporation

IT IS A pleasure to have the opportunity to briefly summarize the scope of this industrial Noise Conference. It is refreshing to reflect that here is an industrial association that is well out in front pursuing the available facts of the noise problem. Many important facts and concepts have been discussed and, in summing up, I shall try to touch briefly on the salient points to bring them again to your mind.

About one-fourth of the men applying for jobs in industry have hearing impairment.

Prolonged exposure to intense noise may cause permanent hearing loss.

Criteria for safe levels of exposure and for measurement of hearing loss need further study.

In some states, including Wisconsin and New York, noise-induced hearing loss that occurred during employment is compensable. In both of these states a six-month waiting period between termination of exposure and assessment of hearing loss is required by law. Wisconsin requires a minimum loss of 17 db to be compensable. New York apparently has no minimum loss requirement.

Hearing loss where no pre-employment examination has been recorded cannot possibly be apportioned among previous employers.

Industrial audiometric measurements are an indispensable part of any hearing conservation program and are necessary in order to protect the interests of the employer and the employee.

In Wisconsin where hearing evaluation has been encouraged and made an inconspicuous part of physical examination programs from preschool age on into employment, the public has become interested in hearing conservation. Labor-management relations have not been disturbed and no great number of hearing loss claims have resulted.

New York employers are active in noise control and in providing personal hearing protection, but few except the very large plants have a program of audiometric examination. However, an example of one plant employing less than 500 persons in which an otologist-directed full audiometric program has been in successful operation for four years was cited. There has been no agitation, no labor-management prob-

lems and no claims filed. Both the management and the employees feel the program has been beneficial. The equipment cost about $1500 or less than a quarter of the cost of an award for a total hearing loss.

There have been no reported increases in hearing loss claims by any company in New York as a result of a hearing conservation program, and plants which have conducted audiometric tests are convinced that this fear has been overemphasized.

Pre-employment audiometric measurements can be used: (a) in the proper and safe placement of the individual having substantial hearing loss; (b) to conserve the hearing of individuals who already have a nerve-type loss; (c) as proof to qualify for benefits of the Second Injury Law; and (d) to relieve the employer of responsibility for occupational hearing loss that existed before the employment if notice is served on previous employer within 90 days.

Recheck audiometric measurements during employment can detect early and minor changes before major damage and can also provide information for possible use in invoking the benefits available under the Second Injury Law.

Regardless of who makes audiometric measurements, and whether they are made in the physician's office, the hospital, or in the industrial plant, minimum requirements for "monitoring audiometry" to determine threshold shifts include the following: (a) a pure tone audiometer, meeting standards set by the American Standards Association; (b) a room or booth with sufficiently low background noise; (c) audiometric measurements must be made only by trained personnel; (d) some method of routinely checking the accuracy or dependability of the measurements must be employed. (This should be over the entire range, not just at threshold level of normal hearing.)

Industrial management should have factual information on the environmental noise level and a noise exposure history of individuals including octave band analyses is advisable in areas where a noise problem exists, which for practical purposes is wherever the noise level is 85 db or more in the 300–600, or 600–1200 cycle per second band.

It is rather obvious that a hearing conservation program in industry to be successful requires the co-operation and co-ordination of a team of people who are trained and experienced in several professional skills. The same may be said of any other occupational health program involving such problems as environmental heat, dust, gases, radiation and so forth. Although the general field is ordinarily divided between man and his environment, with the physician directing those activities dealing directly with the man, and the industrial hygienist in charge of those activities dealing with man's environment, several skills are required.

Perhaps a satisfactory and dependable source of advice on a hearing conservation program would be the same group of people that have provided occupational health and hygiene information in the past; in other words, established channels are usually more dependable than new and unexplored ones.

There was a plea for greater simplification and less complication in hearing conservation programs now obscured by the use of so many technical terms. There is complete sympathy with this point of view, but much of the problem is highly technical and new to many of us. It will require time to enlist the wholehearted co-operation of specialists into putting teamwork and the success of the hearing conservation program ahead of professional pride and jealousies. The *AIHA Industrial Noise Manual* that has been mentioned several times here today is an honest attempt to do just that. Noise measurement is not merely a matter of meter reading but requires training and experience in selecting and properly using and calibrating the measuring equipment.

Only in a screening survey to locate noise sources and roughly evaluate the general noise situation in a plant does the sound level meter provide sufficient information.

Noise exposure data and data for use in noise control planning require an octave band survey. The procedure of a sound survey will depend upon the purpose of the survey, the scope of the survey and the characteristics of the sound sources.

All noise measuring equipment must be carefully checked and calibrated before leaving the headquarters. It must be transported with care and respect, and periodically checked while on the job if the results are to be reliable.

Noise control requires an understanding of the sources of noise such as air flow, impact, vibration and friction, as well as the application of basic control principles such as finding a quieter way to do the job, interrupting or lengthening the noise path between the noise source and the man; and where these methods do not suffice, providing and using personal ear protective equipment.

From the first, these Conferences have stressed the importance of noise control, and in addition to the scores of examples described in the reports of former conferences, new ones or new

approaches to old ones were described today; the use of acoustic material for controlling the reflection or reverberation of noise from the walls and ceiling in the room was discussed today and here the ultimate in performance approaches that of an opening of equal area.

A successful air flow muffler for corrosive gases was described. A lining for tumblers was described and demonstrated.

Two examples were given of methods used in studying noise sources of machines with a view toward quieting their operation. This will become more and more the responsibility of machine manufacturers. One of the more fruitful approaches to the problem of noise control is a search for simplification in the methodology of studying noise sources in machines and better education of master mechanics and purchasing agents in the specification of acceptable noise characteristics for new machines.

An example was cited where sponge rubber proved to be an effective damping agent especially in the lower frequency bands when placed between a large 3 x 10-foot heavy aluminum plate and the plywood-rubber-plywood sandwich upon which the plate rested while being worked with a pneumatic hammer.

The control of noise from jet airplanes was discussed. I think all of us will agree that this project has presented some major engineering problems.

Unless one belongs to the school that is waiting for science to provide cheap and easy noise control methods, each of us can recognize ways of applying some of the techniques presented here today to the solution or alleviation, at least, of some of our own noise problems.

Handbook on Beta-Ray Sources

THE NATIONAL Bureau of Standards Handbook 66, *Safe Design and Use of Industrial Beta-Ray Sources* was issued on May 28, 1958. This handbook has been prepared to serve as a guide toward safe design, manufacture, installation, use, maintenance, and disposal of beta-ray sealed sources for industrial applications. A generalized discussion of the many aspects of personnel protection is given rather than a set of rigid safety rules.

The book contains a glossary of definitions, and chapters are included on radiation exposure, selection of radioactive materials, prototype testing, instruction manuals, labels, working conditions, accidents entailing radiation hazards, and several chapters dealing with the handling of sources. There are two appendices: a listing of pertinent laws and regulations, and maximum permissible exposure limits.

Information contained in this handbook should be very helpful to those needing to comply with the radiation protection regulations issued by the Atomic Energy Commission and other federal and state agencies. The book was prepared, under the sponsorship of the National Bureau of Standards, by the Sub-Committee on Sealed Beta-Ray Sources of American Standards Association Z54 Sectional Committee. Copies may be obtained for 20 cents each from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

HYGIENIC GUIDE SERIES

Diborane*

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 0.1 part of gas per million parts of air, by volume (ppm).[1] Further use experience is needed to confirm this value.

(1) *Basis for Recommendation:* Toxicological observations of animals,[2, 6, 7] and limited human experience.[9, 10]

B. SEVERITY OF HAZARDS:

(1) *Health:* Extra hazardous by inhalation. Effects are chiefly on the lungs, high exposures resulting in pulmonary edema, congestion and hemorrhage.[6] Chills, cough, and tightness in the chest are common signs of overexposure. Repeated exposures to low concentrations may increase tendency toward respiratory infection.

(2) *Fire:* Extra hazardous. May explode when mixed rapidly with air. Care must be taken to avoid electric discharge in areas of greater than 1% diborane concentration. Mixtures of 2–25% with air detonate when sparked, the most violent explosion occurring in a mixture containing 10% in air.[6] Diborane burns in air to B_2O_3 and H_2O.

C. SHORT EXPOSURE TOLERANCE: Not known for man; dogs tolerated 6–14 ppm diborane for periods of 45 minutes to 4 hours with some pulmonary edema.[7]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown for man, but concentrations greater than 300 ppm for a few minutes might be expected to produce serious consequences.[6] (No human fatalities from exposure to diborane have been reported, but there have been some serious illnesses.)[9, 10]

II. Significant Properties

A gas of nauseating odor, hydrolyzing rapidly on contact with water to produce boric acid, hydrogen, and heat.

Chemical formula:	B_2H_6
Molecular weight:	27.6
Relative vapor density:	0.95 (air = 1)
Boiling point:	−92.5°C
Solubility:	Extensive in ether; slight in carbon tetrachloride, dioxane, medicinal mineral oil, carbon disulfide. Reacts rapidly in water.
Odor threshold:	2–4 ppm (2–4 mg/m³)
At 25°C and 760 mm Hg,	
1 ppm of gas:	0.001145 mg/liter
1 mg/liter gas:	873 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Recognized by "nauseating" odor (not a reliable warning of toxic exposure). Employed as high energy fuel intermediate.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation:* None available. Monitoring instruments are under development.

(2) *Chemical:* Collection in bromine in glacial acetic acid, saturated with potassium bromide, in an all-glass bubbler, with subsequent spectrophotometry at 270 mμ[4]. This is specific for diborane.

Collection in acidified water in an

* The following have assisted the Hygienic Guides Committee in the preparation of this Guide: William H. Hill, Ph.D. (University of Pittsburgh); Keith H. Jacobson, Ph.D. (Army Chemical Center); George J. Levinskas, Ph.D. (American Cyanamid Co.); George Roush, Jr., M.D. (Callery Chemical Co.); Joseph L. Svirbely, Ph.D. (R. A. Taft Sanitary Engineering Center).

all-glass bubbler, with subsequent determination of the boric acid by the Carmine method of Hatcher and Wilcox.[5, 8] Large amounts may be determined by titration of the boric acid in a mannitol-NaOH solution.[5, 11] These two last methods are not specific for boron hydrides.

C. RECOMMENDED CONTROL PROCEDURES: Stainless steel and commercial steel cylinders have been used for storage and shipment. Low temperatures (less than −20°C) are required for prolonged storage in stainless steel cylinders only. Natural rubber is rapidly attacked, but materials such as stainless steel, lead, Monel, copper, brass, paraffin, Glyptol, and Kel-F are generally unaffected. Regulator valves with Kel-F seats and gold plated diaphragms are to be used for cylinders containing diborane. Maintain workroom air concentrations below 0.1 ppm by process enclosure and/or ventilation. Respiratory protective equipment of the self-contained oxygen type should be readily available. Training of potentially exposed personnel is important, particularly in the use of such equipment. Very high volume ventilating equipment should be available for rapid ventilation of the area in case of spills.

All apparatus should be flushed with dry nitrogen before introduction of diborane. Work should be done in mechanically ventilated hoods, with a minimum face velocity of 100 feet per minute. Use "soft" wall with ¼-inch steel plate for protection of workers when this is not possible.

When leaks occur, clear area of personnel immediately and mechanically ventilate to a maximum atmospheric concentration of 1%. Then use emergency respiratory protective equipment during repair operations.

Use chemical type goggles for eye protection at all times.

IV. Specific Procedures

A. FIRST AID: Remove immediately from exposure. Place individual at complete bed rest. Call a physician.

B. SPECIAL MEDICAL PROCEDURES:

(1) *Preplacement:* Individuals with preexisting pulmonary disease, or those highly susceptible to respiratory infection, should not be exposed.

(2) *Treatment of Acute Exposures:* Promptly put patient at complete bed rest. Immediately perform medical examination to determine extent of pulmonary injury. Oxygen may relieve uncontrollable coughing. If early, transient, asthmatic breathing is present, pulmonary edema may (rarely) occur later. Such patients should be kept under constant medical supervision until indications of edema have disappeared. The blood pressure, pulse, and respiratory rates should be noted at frequent intervals. Oxygen should be used as indicated and patient followed for signs of secondary infection.

If tremors should occur, supportive treatment for central nervous system involvement may be necessary.

(3) *Periodic Medical Examinations:* Individuals repeatedly exposed to low concentrations of diborane should have medical examinations. Those who have had acute exposures should be followed by medical examinations, including chest X-rays.

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Pentaborane*

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): Below 0.01 parts of vapor per million parts of air, by volume (ppm). Further industrial experience relating exposure and human response is needed to establish a safe level.

(1) *Basis for Recommendation:* Toxicological observations on animals,[5, 4, 9] and human experience.[6, 8]

B. SEVERITY OF HAZARDS:

(1) *Health:* Extra hazardous by inhalation, ingestion, or skin absorption. Acute and chronic exposures produce signs and symptoms referrable to the central nervous system: "lightheadedness", hiccups, drowsiness, nausea, tremors, jerky movements, cramps and pain in abdominal and thigh muscles, profuse sweating, photophobia, increased respiratory and heart rates. May also cause kidney and liver damage. Effects may occur following extremely short exposures.

(2) *Fire:* Highly explosive. Must be treated as though it were spontaneously flammable in air. Flushing spilled material with small amounts of water causes fire, and produces various boron hydrides, including decaborane.

C. SHORT EXPOSURE TOLERANCE: Unknown, for man, but a few parts per million for a few minutes may result in serious effects. In mice, 5 ppm for four hours caused death of all animals.[3] The LC_{50} for rats exposed four hours is 6 ppm and for mice, 3 ppm.[7]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown, for men, but levels around 250 ppm proved uniformly fatal to mice and rats in 15 minutes.[9]

II. Significant Properties

Volatile liquid with a characteristic odor. Hydrolyzes slowly in water, producing boric acid and hydrogen.

Chemical formula:	B_5H_9
Molecular weight:	63.2
Specific gravity:	0.61 at 0° C.
Boiling point:	58° C.
Relative vapor density:	2.18 (air = 1)
Vapor pressure:	66 mm at 0° C.
Solubility:	Extensive in benzene, carbon tetrachloride, carbon disulfide, ether, heptane, cyclohexane; hydrolyzes very slowly in water at room temperature; vigorous reaction in water-dioxane mixtures with 77% hydrolysis in 100 seconds.
Odor threshold:	1 ppm (2.5 mg/m³)[1]
At 25° C. and 760 mm Hg,	
1 ppm vapor:	0.00258 mg/liter
1 mg/liter vapor:	1 mg/liter vapor:

III. Industrial Hygiene Practice

A. RECOGNITION: Odor is not a reliable index of toxic exposure.

B. EVALUATION OF EXPOSURES:

(1) *Direct instrumentation:* None available. Monitoring instruments are under development.

(2) *Chemical:* No satisfactory method specific for pentaborane. Collection on specially activated carbon, with subsequent hydrolysis and determination as boric acid seems best.[2]

C. RECOMMENDED CONTROL PROCEDURES: Pentaborane should be stored in stainless steel cylinders. Natural rubber is readily attacked. Flush out all apparatus with dry nitrogen before introducing pentaborane. Work in hoods. Use "soft" wall with ¼-inch steel plate for protection of workers when this is not possible.

Maintain workroom atmospheres as near to zero concentration as possible

* The following have assisted the Hygienic Guides Committee in the preparation of this Guide: William H. Hill, Ph.D. (University of Pittsburgh); Keith H. Jacobson, Ph.D. (Army Chemical Center); George J. Levinskas, Ph.D. (American Cyanamid Co.); George Roush, Jr., M.D. (Callery Chemical Co.); Joseph L. Svirbely, Ph.D. (R. A. Taft Sanitary Engineering Center).

by process enclosure and ventilation. Respiratory protective equipment of the self-contained oxygen type should be readily available. Indoctrination in the handling and disposal of pentaborane should be rigidly carried out, as well as in the use of emergency respiratory protective equipment. Animal exposure studies indicate temporary protection against low concentrations of pentaborane is obtained by a chemical cartridge respriator containing activated carbon.[5] However, it is not known whether commercially available cartridges and cannisters are effective for human exposure.

When spills or leaks occur, *immediately* clear area of personnel. Very high volume ventilating equipment should be available for rapid ventilation of the area. Decontaminate, wearing respiratory protective equipment, with 1–5% aqueous solutions of either triethanolamine or ammonia.

Use chemical type goggles for eye protection at all times.

IV. Specific Procedures

A. First aid: Remove immediately from exposure. Place individual at bed rest. Call a physician. For skin contact, decontaminate immediately with 1–5% aqueous triethanolamine or 3% aqueous ammonia. The complex formed is still toxic, and must be flushed with water.

B. Special medical procedures:

(1) *Preplacement:* Individuals with preexisting heart, liver, or kidney disease should not be exposed.

(2) *Treatment of Acute Exposures:* Promptly put patient at complete bed rest. There may be a latent period of several hours before symptoms. With onset of drowsiness, fatigue, tremors, or light headedness, patient should be placed in care of physician. Evaluation of liver and kidney function should be done. Supportive care should be given as indicated. Barbiturates may be of value.

(3) *Periodic Medical Examinations:* Individuals repeatedly exposed to low concentrations of pentaborane should have medical examinations, as well as those who have had acute exposures.

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Cresol (Cresylic Acid)

(Mixture of ortho-, meta-, and para- isomers)

I. Hygienic Standards

A. Recommended Maximum Atmospheric Concentration (8 hours): 5 parts of vapor (all isomers) per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation:* Animal studies, human exposures, and analogy with phenol.[2, 3, 10]

B. Severity of Hazards:

(1) *Health:*[6] Moderate for chronic; moderate to severe for acute exposure. May be absorbed through the skin, gastro-intestinal tract, and lungs. Acute exposures by all routes of absorption may cause muscular weakness, gastro-intestinal disturbances, severe depression, collapse, and

death. However, due to its low vapor pressure, cresol, under most conditions of use, would not present an acute inhalation hazard. While the effects are primarily on the central nervous system, there may also occur edema of the lungs, kidneys, liver, pancreas, and spleen. Chronic exposures result in digestive disturbances, damage to the liver and kidneys, mental disturbances, and skin eruptions. Cresol has a marked corrosive action on any tissue, producing burns and dermatitis. A few individuals are extremely sensitive.[8] While meta-cresol is generally considered the least toxic, and para-cresol the most toxic, the differences in degree for the three isomers for practical purposes are negligible.

(2) *Fire:* Moderate. Flash points (closed cup) are: ortho-cresol, 81C (178F); meta-cresol, 86C (187F); para-cresol, 86C (187F), and commercial cresol, 43.5C (110.3F).

C. Short Exposure Tolerance: No data available on concentrations of vapors in the air that are hazardous for short exposures. Extensive skin contact may be fatal in a very short time.

D. Atmospheric Concentration Immediately Hazardous to Life: Not known. Rats were reported to survive 8 hours inhalation of substantially saturated vapors at room temptrature.[9]

II. Significant Properties

Commerical cresol or cresylic acid is a mixture of ortho-, meta-, and para-cresols, and usually also contains small amounts of phenol and xylenols. It is a colorless liquid which turns brown on exposure to air. Ortho- and para-cresol are colorless crystals and meta-cresol is a colorless liquid. Cresylic acid has an odor resembling that of creosote.

Chemical formula:	$C_6H_4(CH_3)OH$
Molecular weight:	108.1
Specific gravity:	
Commercial cresol: (Cresylic Acid)	Range 1.030–1.045 (25C)
Melting point:	
Commercial cresol: (Cresylic Acid)	Liquid at ordinary temperature
Boiling point:	
Commercial cresol: (Cresylic Acid)	Range 185–205C
Vapor pressure:	
Commercial cresol: (Cresylic Acid)	Not available
ortho-cresol:	3.55 mm Hg at 60C
meta-cresol:	1.77 mm Hg at 60C
para-cresol:	1.7 mm Hg at 60C
Relative vapor density:	3.72 (air = 1)
Solubility:	
Commercial cresol:	About 1 part per 100 parts water; soluble in alcohol and caustic alkalis.
At 25 C and 760 mm Hg,	
1 ppm of vapor:	0.00442 mg/liter
1 mg/liter of vapor:	226 parts per million

III. Industrial Hygiene Practice

A. Recognition: By its characteristic odor, resembling that of creosote. Major uses are in disinfectants and fumigating formulations, in the production of synthetic resins, and as an intermediate in the chemical industry.

B. Evaluation of Exposure:

(1) *Direct instrumentation:* None available.

(2) *Chemical method:* Same as for phenol, consisting of absorption in dilute alkali, followed by colorimetric determination with diazotized p-nitroaniline reagent[7] or absorption in spectrograde alcohol, with direct determination by ultraviolet spectrophotometry. Color comparisons must be made with cresol of same isomeric composition, since phenol and many other compounds interfere.[4, 5]

C. Recommended Control Procedures: Maintain workroom atmospheres below 5 ppm by process enclosure and/or ventilation. Avoid skin contact.

IV. Specific Procedures

A. First Aid: Remove from contaminated area. If skin or eyes are affected, wash copiously with water; if skin area affected is large, remove clothes promptly under shower. In oral poisoning, quickly induce vomiting, if individual is conscious.

B. Specific Medical Procedures: Individuals with a known sensitivity to cresol or Lysol, and with evidence of liver or kidney disease should be excluded from any exposure to cresol. Treatment of

exposure is largely symptomatic. If vomiting has not been effectively induced in oral poisoning, gastric lavage should be used.

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Ethylene Glycol Mono-n-Butyl Ether

(2-butoxyethanol)

I. Hygienic Standards

A. Recommended Maximum Atmospheric Concentration (8 hours): 50 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation:* Experimental studies in animals and humans.[3]

B. Severity of Hazards:

(1) *Health:* Moderate, for both acute and chronic exposures. Eye and respiratory tract irritation, narcosis, blood, kidney, and, to a lesser degree, liver damage can be produced in animals from single or repeated exposures at concentrations less than saturation. It is considered to be the most toxic of the commonly used glycol ethers and produces specific hemolytic effects. Animals are thought to be more susceptible to hemolytic effects than man.[3] Exposures to 100 ppm result in eye, nose, and throat irritation in some persons. Probably because of its low volatility only one case of possible illness has been reported in an exposed workman. It is rapidly absorbed through the skin and repeated skin contact is hazardous.[3]

(2) *Fire:* Low. Flash point is 60.6°C (141°F) (closed cup). Ignition temperature is 244°C (472°F). Explosive limits are 1.1 to 10.6% by volume.

C. Short Exposure Tolerance: 200 ppm for a single eight-hour period produced no objective evidence of injury in carefully observed persons exposed experimentally, but did cause immediate irritation of nose and throat, as did 100 ppm.[3] Inhalation of concentrations of 500 ppm for several hours may result in injury.[3]

D. Atmospheric Concentration Immediately Hazardous to Life: Unknown.

II. Significant Properties

Ethylene glycol mono-n-butyl ether is a colorless liquid with a mild, disagreeable odor. Its common trade name is Butyl Cellosolve.

Chemical formula:	$C_4H_9OCH_2CH_2OH$
Molecular weight:	118.2
Specific gravity:	0.9019 (20/20°C)
Boiling point:	171.2°C
Relative vapor density:	4.07 (air = 1)
Vapor pressure:	0.76 mm Hg at 20°C
Solubility:	Soluble in water and most organic solvents.
At 25°C and 760 mm Hg,	
1 ppm of vapor:	.00483 mg/liter
1 mg/liter of vapor:	207 ppm
Saturated vapor at room temperature:	approx. 1000 ppm

Note: Dr. Henry F. Smyth, Jr. (Mellon Institute) assisted the Hygienic Guides Committee in the preparation of this Guide.

III. Industrial Hygiene Practice

A. RECOGNITION: Used as a solvent for cellulose esters, in lacquers and other surface coatings, in dry cleaning, soaps, hydraulic fluids and metal cleaners.

B. EVALUATION OF EXPOSURES:

(1) *Physical methods:* No direct instrumentation available. Carpenter, et al,[3] used a portable interferometer for determining chamber concentrations. Ethylene glycol mono-n-butyl ether has a suitable infrared absorption curve but its use in industrial hygiene has not been reported.

(2) *Chemical methods:* Absorption in water followed by dichromate oxidation, as in method of Werner and Mitchell,[4] may be used, but is not specific.

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom air concentrations below 50 ppm. Prevent repeated skin contact by process design or protective clothing.

IV. Specific Procedures

A. FIRST AID. Usually not applicable.

B. SPECIAL MEDICAL PROCEDURES: The preplacement examinations should give consideration to pre-existing blood and renal disorders. Medical examination of exposed individuals should include blood counts and red cell fragility tests. The latter is suggested by findings in rats, but has not been confirmed in humans.[3] The urine should be examined with particular reference to red cells, hemoglobin, or casts.[2]

V. Literature References

1. American Conference of Governmental Industrial Hygienists. *AMA Arch. Ind. Health, 16:* 261, 1957.
2. BROWNING, E.: Toxicity of Industrial Organic Solvents. Chemical Publishing Co., Inc., New York, 1953.
3. CARPENTER, C. P., ET AL: *AMA Arch. Ind. Health, 14:* 114, 1956.
4. WERNER, H. W., AND MITCHELL, J. L.: *Ind. and Eng. Chem., Anal. Ed., 15:* 375, 1953.

Epoxy Resin Systems*

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): Not established. The principal airborne materials are the vapors of various curing agents, and in some instances, dust from machining of resins. Grandjean[2] found the concentration of one type of curing agent (triethylene tetramine) to vary from less than 0.15 mg/m³ to 0.59 mg/m³.

B. SEVERITY OF HAZARDS:

(1) *Health:* Acute toxicity, low. Disability results from skin irritation and sensitivity to curing agents, hardeners, and solvents, and to uncured or incompletely cured resins. There is also a potential hazard of asthmatic-like reactions to certain types of amine curing agents,[1, 4, 5, 6] although this has not been reported.

(2) *Fire:* Will depend on the type of curing agents, thinner, etc.

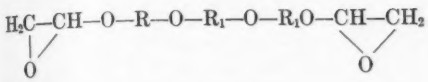
C. SHORT EXPOSURE TOLERANCE: Effects unlikely from acute exposure to uncured or cured resins. There may be a hazard from volatile amines, although there is no available data on the range of air concentrations encountered during use.

D. ATMOSPHERIC CONCENTRATIONS IMMEDIATELY HAZARDOUS TO LIFE: Unknown. Probably not attainable at or near room temperature.

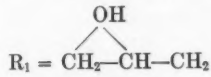
II. Significant Properties[4]

Uncured resins are usually long-chain prepolymers which are viscous liquids or solids. They are generally polyethers with terminal epoxy groups such as indicated in the type formula below.[4] Many variations are possible and in some instances, the curing agents may become part of the cross linked polymer.

* The use of epoxy resins involves materials other than the resins, such as curing agents, solvents, diluents, etc. Some of these may present health hazards. This Hygienic Guide is intended to cover in general the health problems encountered in exposure to epoxy resin systems, rather than to delineate those of a specific material. Because of the variety of materials used and because of the rapidly changing technology, the manufacturer of a specific material should be consulted on handling precautions.



R = bis phenol group



Molecular weight of uncured resins:	300 to 6,000
Specific gravity:	1.11 to 1.23
Boiling point, density of vapors, and vapor pressure:	Highly variable.
Solubility of resins:	Soluble in most organic solvents.

Curing agents may be amines, acid anhydrides, or reactive diluents. Examples are diethylene triamine, phthalic anhydride, phenyl glycidyl ether.

III. Industrial Hygiene Practice

A. RECOGNITION: Widely used in surface coatings and paints, laminates, castings, molding compounds, tools and dies, foamed and expanded plastics, electrical insulations, adhesives (particularly plastic to metal formulations), resinous putty, cements and mortars. May be mixed with other types of polymers.

B. EVALUATION OF EXPOSURES: Measurement of airborne aliphatic amines can be made by suitable chemical methods.[2]

C. RECOMMENDED CONTROL PROCEDURES:

(1) *Ventilation:* Ventilation is usually necessary. Local exhaust should be provided in the region where the curing agent and resin are mixed. Good practice requires a face velocity of not less than 100 feet per minute. Regional exhaust or good general ventilation may be necessary for laying-up and curing areas.

(2) *Personal cleanliness:* A definite program of education of all workers is essential. The uncured resins and curing agents should be kept off the skin or removed promptly, if there is accidental exposure. Gloves, aprons, and clean uniforms should be used. It is particularly important to provide respiratory, eye, and skin protection during mixing of the liquid epoxys. During pouring or laying-up operations, skin protection is definitely required.

Convenient hand washing facilities should be available in the work room. The so-called waterless cleaners and acid type hand cleaners are relatively effective and safe. If solvents are used they should be limited to very small areas of skin and should preferably be alcohol or acetone rather than petroleum solvents. Disposable towels only should be used. Eye fountains should be available, particularly in areas where aliphatic amines are being handled. Smoking should be prohibited in the working area. Showers should be available and their routine use should be encouraged. In case of unusual contamination, showers should be required.

(3) *Good housekeeping:* Special work areas, isolated from other operations and personnel traffic, are suggested. Equipment should not be used for other operations unless thoroughly decontaminated. Special receptacles for waste collection should be used. Covering of work surfaces and lining containers with paper aids in cleanup.

IV. Specific Procedures

A. FIRST AID: Wash with mild soap and water all affected skin areas at once. Irrigate eyes promptly for at least 15 minutes with water and then refer to a physician.

B. SPECIAL MEDICAL PROCEDURES: Avoid assigning persons with active skin disease or pulmonary allergies to production operations requiring contact with curing agents and uncured epoxy resins. Where skin reactions have occurred among such personnel, no treatment should be attempted except through the plant physician or a recognized dermatologist.

V. Literature References

1. DERNEHL, CARL: *Ind. Med. & Surg., 20:* 541 (1951).
2. GRANDJEAN, E.: *Brit. J. Ind. Med., 14:* 1 (1957).
3. HINE, C. H., et al.: *AMA Arch. Ind. Health, 17:* 129 (1958).
4. LEE AND NEVILLE: *Epoxy Resins*, p. 294. McGraw-Hill Book Co., Inc. New York (1957).
5. MORRIS, G. E.: *AMA Arch. Derm., 76:* 757 (1957).
6. SAVITT, L. E.: *AMA Arch. Derm., 71:* 212 (1955).

Zirconium

I. Hygienic Standards

A. Recommended Maximum Atmospheric Concentration (8 hours): 5 milligrams (calculated as zirconium) per cubic meter of air (mg/m^3).[2]

(1) *Basis for Recommendation:* Animal experimentation,[5, 6, 7, 10] and human experience in industry.

B. Severity of Hazards:

(1) *Health:* Low, for both acute and chronic exposures. Administration of zirconium or its compounds, orally or by inhalation in animals, produces no significant chronic or acute effects.[5, 6] Application of ointments containing zirconium compounds to the skin of animals[7] and humans[13] is reported to produce no irritation, sensitization, or absorption, although more recent work suggests some reaction from sodium zirconium lactate.[11] No occupational case of systemic poisoning has been reported.

(2) *Fire:* Extreme fire and explosion hazard when in powdered or dust form.[1, 8] High fire hazard in the form of chips, turnings, or sponge. Dust clouds will frequently become self ignited and explode if mean particle size is less than 10 microns. Very low energy ignition source required for ignition of dust clouds of even larger particles. Lower explosive limit may be as low as 0.04 ounces per cubic foot and pressures up to 78 psi may be attained.[8] Zirconium sponge, chips, turnings, and dust are easily ignited with a match. A moisture content of 5 to 15% increases the combustion rate of zirconium powder, while 25% moisture content eliminates the fire hazard, unless evolved hydrogen is permitted to accumulate. Zirconium in a form having any dimension under $\frac{1}{32}$ in. should be stored in the presence of at least 25% water by weight.[2] Ingots, bars, and rods are relatively nonflammable. Zirconium in sheet form and zirconium alloys present a surface explosion hazard in pickling and etching operations in nitric acid. The addition of fluoride ion to a 1.0 molar concentration inhibits formation of an explosive surface.[2]

II. Significant Properties

Zirconium is a white-gray solid commercially available in massive forms such as ingots, bars, rods, or foil, and as powder.

Chemical formula:	Zr
Molecular weight:	91.2
Specific gravity:	6.4
Melting point:	1900°C
Solubility:	In hydrofluoric acid and aqua regia. Slightly soluble in other acids

III. Industrial Hygiene Practice

A. Recognition: No identifying characteristics of taste, odor, or irritation. Until recently, little used in industry (flares, flash bulbs, etc.). At present, it is produced in large quantities as massive forms or as powders, for use by the Atomic Energy Commission.

B. Evaluation of Exposures:

(1) *Direct instrumentation:* None available.

(2) *Chemical:* Determination by spectrographic procedures is recommended.[12] Other suggested methods are using a dust sampling device and subsequent zirconium determination by (a) electrophoresis and color development by tumeric; (b) method of Bricker and Waterbury;[4] or (c) method of Hayes and Jones.[9]

C. Recommended Control Procedures: Control dust production with water-wash dust collector. Ducts should be short, straight sections with conveniently spaced clean-out doors. Dust collectors should be separate from other ventilation systems. Machining should be performed in the dry state or with the use of high flash neutral mineral oil coolants. No soluble or vegetable oil coolants should be used. Chips and turnings should be placed in covered metal waste cans and removed from the building each day. Scrap zirconium should be burned to the nonflammable oxide before storage. The burning should be so performed that the operator will be protected in the event of an explosion.

Safety goggles or face shields, fire resistant clothing without pockets, cuffs, or other recesses, and leather gloves should be worn. Trousers should be worn over high top leather shoes. Safety shoes should be provided. Only approved graphite type (such as G-1 powder) or salt-resin base (such as Met-L-X) extinguishing agents for metallic fires should be used.

IV. Specific Procedures

A. First Aid: Eyes should be irrigated by large amounts of water for 15 minutes, followed by medical attention. Zirconium which has penetrated the skin should be removed before dressing the wound.

B. Special Medical Procedures: No special requirements for placement or treatment appear necessary.

V. Literature References

1. Allison, W. W.: WAPD-TM-14, AEC Research and Development Report, Sept. 1956, Contract AT-11-1-Gen. 14. Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C.
2. Allison, W. W.: WAPD-TM-17, Oct. 1, 1956, Contract AT-11-1-Gen. 14. Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C.
3. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health, 16:* 262, 1957.
4. Bricker, C. E., and Waterbury, G. R.: *Anal. Chem., 29:* 558, 1957.
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7. Harrison, J. W. E., et al: *J. Pharm. and Exper. Therap., 102:* 179, 1951.
8. Hartman, I., et al: Bureau of Mines Rept. Invest. 4835, 1951.
9. Hayes, W. G., and Jones, E. W.: *Ind. and Eng. Chem., Anal. Ed., 13:* 603, 1941.
10. McClinton, L. T., and Schubert, J.: *J. Pharm. and Exper. Therap., 94:* 1, 1948.
11. Sheard, Charles, et al: *J.A.M.A., 164:* 1085, 1957.
12. Steadman, L. T. (University of Rochester): Personal Communication.
13. Strauss, R. E., and Bruck, C. R.: *J. of Invest. Dermat., 20:* 411, 1953.

Because of space limitations, it is impossible to list all methods of exposure evaluation. The selections have been made on the basis of current usage, reliability, and applicability to the usual industrial type of exposure. Any specific evaluation and/or control problem will involve professional judgment. This can best be done by professional industrial hygiene personnel.

Respiratory protective devices are commercially available. Their use, however, should be confined to emergency or intermittent exposures and not relied upon as primary means of hazard control.

A relative scale is used for rating the severity of hazards: nil, low, moderate, high, and extra hazardous.

Hygienic Guides Committee

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Obituaries

Francis F. Heyroth died at his home on August 19, 1958, after a prolonged illness. He had retired in 1957 from his post as Assistant Director and Associate Professor of Industrial Toxicology at the Kettering Laboratory, University of Cinsinnati. Dr. Heyroth was widely known for his research and knowledge in industrial toxicology, fluoridation, and cancer. He had served for eight years as Medical Supervisor of the Ethyl Corporation of New York. He was active in many scientific organizations including A.I.H.A., National Advisory Council on Dental Research, and the American Chemical Society. The Bachelor of Science, Doctor of Medicine, and Doctor of Philosophy degrees were earned by him at the University of Cincinnati.

Lester M. Merritt, a member of A.I.H.A. for many years, died on May 30, 1958. He had been with the Industrial Commission of Ohio doing industrial hygiene and safety work since 1939. He taught safety and safety education at Ohio State University and published often in these fields. He was an active member also of the American Conference of Governemental Industrial Hygienists, the Ohio Society of Professional Engineers, American Ceramic Society, National Institute of Ceramic Engineers, and a member of academic and veteran's organizations.

Everett W. Probst, Medical Director of Reation Motors, Inc., was taken by death the latter part of May 1958. A graduate of New York University School of Medicine, he had a varied experience in industrial medicine including service with the Army Medical Corps at Picatiny Arsenal. He was a member of A.I.H.A. for fifteen years, having joined in 1943.

Air Pollution Conference

The National Conference on Air Pollution will be held at the Sheraton-Park Hotel in Washington, D. C., on November 18, 19, and 20, 1958. The interdisciplinary meeting has been called by Dr. Leroy E. Burney, Surgeon General, Public Health Service, U. S. Department of Health, Education, and Welfare.

For information, write Malcolm C. Hope, Exec. Sec., NCAP, Public Health Service, Washington, 25, D. C.

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